BOTANY

PART - 2

CLASS XI

SYLLABUS : HIGHER SECONDARY
- FIRST YEAR - BOTANY

Unit 1 : Biodiversity (20 hours)

Systematics : Two Kingdom and Five Kingdom Systems - Salient features of various Plant Groups (Algae, Fungi, Bryophytes, Pteridophytes and Gymnosperms) - Viruses - Bacteria - Algae : Spirogyra - Fungi : Mucor - Bryophyta : Riccia - Pteridophyta : Nephrolepsis - Gymnosperms : Cycas.

Unit 2 : Cell Biology (20 hours)

Cells as the basic Unit of Life - Cell Theory - Prokaryotic and Eukaryotic cells (Plant Cell) - Light Microscope and Electron Microscope (TEM & SEM) - Ultra Structure of Prokaryotic and Eukaryotic Cells - Cell Wall - Cell Membrane (Fluid Mosaic Model) Membrane Transport Model - Cell Organelles : Nucleus, Mitochondria, Plastid, Ribosomes - Cell Divisions : Amitosis, Mitosis and Meiosis and their significance.

Unit 3 : Plant Morphology (10 hours)

Structure and modifications of Root, Stem and Leaf - Structure and types of Inflorescences - Structure and types of flowers, fruits and seeds

Unit 4 : Genetics (10 hours)

Concept of Heredity and Variations - Mendel's Laws of Inheritance - Chromosomal basis of Inheritance - Intermediate Inheritance (incomplete Dominance) - Epistasis

Unit 5 : Plant Physiology (30 hours)

Cell as physiological unit - Properties of Protoplasm - Water relations - Absorption and movement - Diffusion, Osmosis, Plasmolysis - Theories of Water Transport - Root pressure - Transpiration pull - Factors affecting rate of Transpiration - Mechanism of Stomatal opening and closing - Potassium ion theory - Factors affecting Stomatal movement - Functions of Minerals - Essential major elements and trace elements - Deficiency symptoms of elements - Theories of Translocation - Translocation of Solutes - Nitrogen Metabolism and Biological Nitrogen Fixation Movements - Geotropism - Phototropism - Turgor Growth Movements - Tropic - Nastic & Nutation.

Unit 6 : Reproduction Biology (30 hours)

Modes of Reproduction in Angiosperms - Vegetative propagation (natural and artificial) - Micropropagation - Sexual Reproduction - Pollination : types - Double fertilization - Development of male and female gametophytes - Development of Dicot Embryo - Parthenogenesis and Parthenocarpy - Germination of Seeds - Parts of Seed - Types of Germination - Abscission & Senescence.

Unit 7 : Environmental Biology (20 hours)

Organisms and environment as factors : Air, Water, Soil, Temperature, Light and Biota - Hydrophytes, Mesophytes, Xerophytes and their adaptations - Natural Resources Types, use and misuse - Conservation of water (RWH) - Ecosystems: (a) Structure & Function, (b) Energy flow, (c) Decomposition, (d) Nutrient Cycling, (e) Major Biomes, Forests - Grasslands, Deserts - Ecological Succession : Mechanism & Types (Hydrosere & Xerosere).

Unit 8 : Practical Work (30 periods)

1. Study of the following plants through specimens and slides and labelled sketches in the Botany Record Book

1.1 Spirogyra

1.2 Mucor

1.3 Riccia

1.4 Neprolepsis

1.5 Cycas

2. Study of the plant cells

2.1 Onion peel : Observe in the microscope and draw labelled sketches

2.2 Hydrilla leaves whole mount in pond water : observe and draw labelled sketches

2.3 Squash preparation of onion root tip : Observe stages of Mitosis and draw labelled sketches

3. Study of modifications of stem and root and draw labelled sketches

3.1 Unddderground root modifications : Radish, Carrot, Beet-root

3.2 Aerial roots : Banyan Prop Roots - Climbiung Root of piper betel

3.3 Underground stem modifications : Potato, Ginger, Onion, Yams

4. Flower : Structure, Vertical Section, Floral Diagram and Floral Form of the following

4.1 Hibiscus

4.2 Datura

5. Physiology Experiments

5..1 Transpiration

(a) Transpiration pull

(b) Ganong's Potometer

5.2 Osmosis

(a) Osmometer - using semipermeable plant memabrane

(b) Potato Osmometer

5.3 Root Pressure : Experiment to demonstrate root pressure in Dicots

6. Germination of Seeds

6.1 Hypogeal type

6.2 Epigeal type (students to do project work)

7. Hydrophytes & Xerophytes

7.1 To study the specimens and write to note

(a) Hydrophytes : Hydrilla / Vallisneria, Eichhornia, Pistia

(b) Xerophytes : Opuntia, Euphorbia tirucalli, E. antiquorum, Aloe, Nerium.

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BOTANY CHAPTERS

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V. PLANT PHYSIOLOGY

1. Cell as a Physiological Unit

Living organisms are made up of structural and functional units called cells. Every cell is made up of several biomolecules and organelles. The organelles are membrane-bound structures involved in specific functions. The organelles are absent in prokaryotic cells; yet a prokaryotic cell also can carry out all the physiological functions required for its metabolism.

The plant cell can be referred to as a physiological unit as it has the capabilities of carrying out physiological functions as a single entity.

The cell wall is a non-living outer limiting layer of the plant cell which provides shape and rigidity to the cell.

The cell wall is followed by the plasma membrane or cell membrane which is selectively permeable involved in the absorption of water by osmosis, and other substances like ions and low molecular weight biomolecules.

The protoplasm which is the physical basis of life includes cytoplasm, nucleus and cellular organelles which are involved in the various physiological processes taking place within the cell. The protoplasm is a water retentive colloid holding 90% of water which is a universal solvent.

The plant cells are characterised by a prominent vacuole holding the cell sap and functioning as an osmo-regulatory organelle of the cell.

Thus the cell is the principal seat of metabolic events.

Nutrition

Among the cell organelles, the **Chloroplast** is the most important structure unique to plant cells and involved in the most important physiological process called **Photosynthesis**. This process is the source of food for life on earth.

Respiration

The organelle of the plant cell involved in cellular respiration is the mitochondrion. This organelle is concerned with the oxidation of food substances to release CO_2, water and energy in the form of Adenosine Triphosphate (ATP).

Protein Synthesis

The synthesis of proteins and their transport is carried out by the ribosomes and the endoplasmic reticulum.

Secretion

Cell secretion takes place by the organelle called the **Golgi body** which is referred to as the **dictyosome** in plants.

The plant is thus able to co-ordinate the physiological activities of the various organelles and behaves as a perfect physiological unit.

Thus the cell is the seat of important physiological functions.

1. a. Properties of Protoplasm

The protoplasm is the living component of the plant cell and involves four parts (i) the cytoplasm, (ii) the vacuoles, (iii) a number of organelles and (iv) the nucleus.

In young cells, the vacuoles are many, small and scattered, whereas in a mature cell, there is a single large vacuole occupying the centre of the cell and the cytoplasm forms a thin peripheral layer around the vacuole.

The Physical Nature of Protoplasm

Many theories have been put forth to expalin the physical nature of the protoplasm.

The Alveolar Foam Theory

Butschili in 1882, said that the protoplasm is a semi-transparent, viscous and slimy substance, essentially a liquid possessing a foaming or alveolar structure.

Colloidal Theory

Wilson Fischer (1894) considered the protoplasm as a polyphase colloidal system.

This theory is a widely accepted one as the protoplasm is seen to exhibit the properties of colloids.

Properties

i. Colloidal System

The protoplasm forms a colloidal system composed of a water phase in which mineral matter is dissolved, also having a protein phase, a fat phase and many minor phases. So it is said to be a **polyphase colloidal** system.

ii. Solation and Gelation

The protoplasm exists mostly as a sol (which is semi-liquid) but sometimes it becomes rigid and is viewed as a gel (which is sem-solid).

$$\text{Sol} \underset{\text{Solation}}{\overset{\text{Gelation}}{\rightleftharpoons}} \text{Gel}$$

iii. Brownian Movement

The particles of the protoplasm show an erratic zig-zag movement. This **random** motion, caused by the uneven bombardment of particle is called **Brownian movement**.

iv. Tyndall Effect

The scattering of a beam of light by the particles of a colloid is termed **tyndall effect**. This is a property of the protoplasm also.

v. Ultrafiltration

The particles of the protoplasm cannot be filtered through ordinary filter paper but can be filtered through ultrafilters such as millipore filters.

vi. Electrical Properties

The particles of the colloid carry an uniform electric charge.

vii. Flocculation or Co-agulation

When the particles of a colloid lose their charges they tend to aggregate and increase in size. As a result they fall out and get precipitated. In other words protoplasm loses its living property.

These properties of the protoplasm indicate that it is a living substance and has rightly been termed as the physical basis of life (*vivum fluidum*).

Chemical Nature of Protoplasm

The major constituent of the protoplasm is water which makes up 90% of it. The dry matter has several organic and inorganic substances. Proteins and other nitrogen-containing compounds constitute the bulk of organic matter. Liquids like fats and oils are also present in small amounts. Compounds consisting of chlorides, phosphates, sulphates and carbonates of magnesium, potassium, sodium, calcium and iron are also present.

Since the protoplasm contains all the chemical constituents required for life, it has been called the **"Physical and Chemical Basis of Life"**.

1.b. Water Relations

Water is the most important substance required for the sustenance of life. The protoplasm which is the physical and chemical basis of life has 90% of water.

Thus the dispersion medium of the protoplasmic colloid is water. Water has a number of special properties by which it becomes the most suitable medium for the organisation of a variety of life's functions rather very easily. Absorbing of substances from the environment, transporting these within and across the cells, mediating important chemical reactions and properly maintaining the shape and forms of organs to bring about their effective functioning are all advantages, the protoplasm possesses due to the presence of water in it. At molecular level water is the donor of electrons / hydrogen in photosynthesis and it is the end product in respiration. Thus it is clear that any factor causing loss of water and subsequent coagulation of protoplasm will eventually lead to death.

As far as plant cells are concerned water absorption for photosynthesis is one of the most essential activities. So water relations in a plant cell are of greater significance and form the fundamental process for the proper functioning of the plant cell.

A typical plant cell consists of cell wall, a central large vacuole filled with an aqueous solution called cell sap, and the cytoplasm. When a plant cell is subjected to movement of water, many factors start operating and these will ultimately determine, a property called water potential of the cell sap. It is the water potential which controls movement of water into and out of the cells.

1.c. Absorption and Movement

Absorption of water

Absorption of water occurs in plants through roots. The zone of water absorption in root is about 20 - 200 mm from the root tip and this is the **root hair zone**. The ultimate units of water absorption are the root hairs. The root hair is a unicellular tubular extension bound by an outer cell wall followed by plasma membrane, enclosing the protoplasm inside. The cytoplasm of the root hair contains a large central vacuole filled with cell sap.

Absorption of water by plants takes place due to the process, osmosis, which is a passive diffusion.

Path of water across the root

The root hairs are unicellular extensions of the roots found extending into the pore spaces of the soil particles. The pore spaces contain water and dissolved minerals in the form of **soil solution**. This water first gets adsorbed to the wall of the root hair, by imbibition thus wetting it. This forms a channel for further absorption of water by the living cells of the root in an active manner. From the root hair water reaches the cells of the rhizodermis, then through the cortical layers the

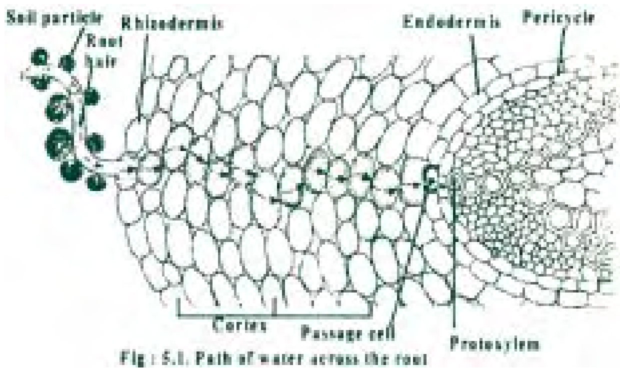


Fig : 5.1. Path of water across the root

water reaches the **passage cells** of the endodermis which are opposite to the **protoxylem points**. The water then passes through the parenchymatous pericycle and reaches the **protoxylem**.

The path of water is in a lateral direction and so is called **lateral transport** of water. Once the water reaches the xylem, it has to be transported in an upward direction to the shoot system and from there to the leaves. This is referred to as **Ascent of Sap**.

Imbibition

Imbibition is the uptake of water or other solvents by non-living substances such as gum, starch or wood causing swelling of these substances. Such substances are called **imbibants**. The phenomenon of imbibition creates a force called **imbibitional force** between the imbibant and the solvent. In plant cells, the cell wall is the imbibant which absorbs water and forms a channel for movement of water into the cell by diffusion and osmosis. Imbibition plays a very important role in most of the activities especially seed germination which involves absorption of water by seed coats, their swelling and rupture causing the emergence of the **radicle** and **plumule**.

Diffusion

Diffusion is the flow of matter, solid, liquids and gases from a region of higher concentration to a region of lower concentration until equilibrium is attained. Examples of diffusion are the smell of perfume, when we open a perfume bottle and the spread of colour when a crystal of potassium permanganate is put into a beaker of water.

When a substance undergoes diffusion, its particles start moving. When the moving particles counter a surface, the surface offers resistance to the impact of diffusing particles. This leads to development of pressure called **diffusion pressure**. Always diffusion occurs from a level of higher diffusion pressure to a level of lower diffusion pressure. A pure solvent has maximum diffusion pressure and addition of solutes lowers the diffusion pressure. The amount by which the diffusion pressure of a solution is lower than that of the pure solvent is called **Diffusion Pressure Deficit** (DPD). But the recent trend is to use the term water potential to explain diffusion of water.

Osmosis

Osmosis is a special type of diffusion of liquids. When two solutions of different concentrations are separated by a selectively permeable membrane, diffusion of water or solvent molecules takes place from the solution of lower concentration to the solution of higher concentration. This process is called **Osmosis**. In other words Osmosis is the diffusion of water or solvent from a region of its higher concentration to a region of its lower concentration through a selectively permeable membrane. This can also be expressed as the movement of water from a region of higher free energy of water or water potential to a region of lower free energy of water potential through a selectively permeable membrane.

Hypertonic, Hypotonic and Isotonic solutions

Imagine a system in which an aqueous solution **A** with high concentration of solute is separated by a selectively permeable membrane from an aqueous solution **B** with a low concentration of solute. Solution A is said to be **hypertonic** to solution B, and solution B **hypotonic** to solution A. In this situation, there will be a net movement of water or solvent molecules through the membrane from the hypotonic solution to the hypertonic solution by osmosis. This will continue until equilibrium is reached, at which point there is no further movement of water and the two solutions are described as **isotonic**.

Demonstration of Osmosis

The process of osmosis may be demonstrated by the simple osmometer which is the thistle funnel experiment.

Potato Osmoscope

Demonstration of osmosis in a living system can be done using the potato osmoscope.

A potato is peeled and one side is flattened which serves as the base. A cavity is made in the potato and is filled with concentrated sugar solution and a pin mark is made to indicate the initial level. This potato is then placed in a beaker containing coloured water for some time.

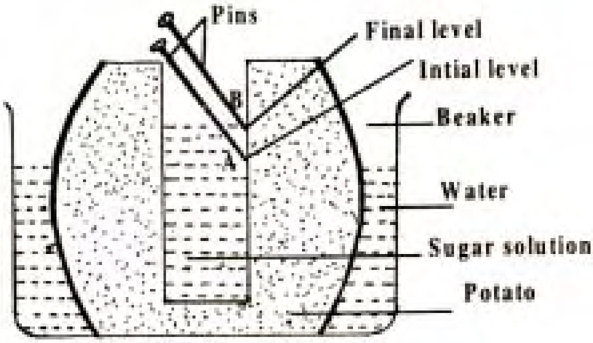


Fig : 5.2. Potato osmoscope

Observation

It is observed that the sugar solution in the cavity of the potato becomes coloured and level rises.

Inference

This proves the entry of water into the sugar solution through the potato tissues which serve as the selective permeable membrane.

Plasmolysis

When a plant cell is placed in hypertonic solution, the process of exosmosis starts and water from the cell sap diffuses out into the solution of external medium. This causes a reduction in the tension of the cell wall and brings about the contraction of protoplasm due to the continuous loss of water. The protoplasm becomes rounded in shape due to contraction and such a cell is said to be **plasmolysed** and the phenomenon is referred to as **plasmolysis**. The initial stage of plasmolysis where the protoplasm just starts leaving the cell wall is called **incipient plasmolysis**.

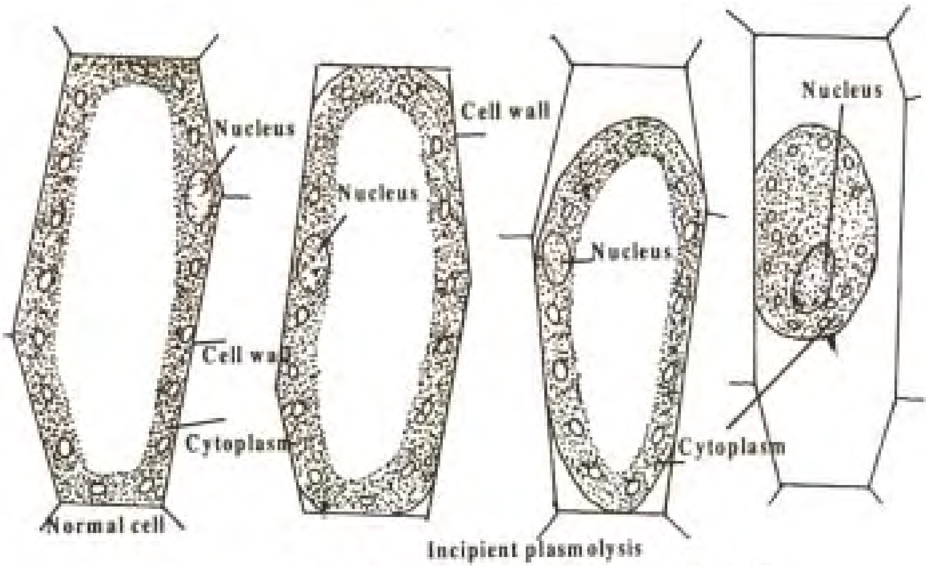


Fig : 5.3. Various stages of plasmolysis in a cell

When a completely plasmolysed cell is again placed in water or a hypotonic solution, endosmosis takes place and the protoplasm regains its original state and shape. i.e., the cell becomes fully turgid. This phenomenon is the reverse of plasmolysis and is called **deplasmolysis**.

Significance of Plasmolysis

1. Helps to understand the living nature of a cell.
2. Helps to preserve meat, jellies and used in pickling as their salting kills bacteria by plasmolysis.

3. Used to prove the permeability of cell wall and selectively permeable nature of plasma membrane.

Osmotic Pressure

Osmotic pressure of a solution is the pressure which must be applied to it in order to prevent the passage of solvent due to osmosis. In other words, it is that pressure which is needed to check the process of osmosis. The term **osmotic potential** is also used in place of osmotic pressure.

Turgor Pressure

When the plant cell is placed in water, it will swell but will not burst. Due to the negative osmotic potential of the cell sap, water moves into the cell and causes the plasma membrane to press against the cell wall. This pressure responsible for pressing the plasma membrane against cell wall is called **turgor pressure**.

Turgor pressure may also be defined as the hydrostatic pressure developed inside the cell on the cell wall due to **endosmosis**.

Wall Pressure

As a result of turgor pressure on the cell wall, the rigid cell wall exerts an equal pressure in the opposite direction called **wall pressure**. Under these conditions, the plant cell is said to be turgid.

When wall pressure becomes equal to turgor pressure, entry of water into the cell stops and the water potential (Psi denoted as ø) becomes equal to that of the environment.

Diffusion Pressure Deficit (DPD) or Suction Pressure

The pressure exerted by diffusing particles is called diffusion pressure. When solute is added, the diffusion pressure of a solution is lowered. The amount by which diffusion pressure of a solution is lower than that of its pure solvent is known as **diffusion pressure deficit** which was described as **suction pressure** by Renner (1915). Recently a new term called water potential is used for DPD but with a negative value.

1.d. Permeability and Water Potential

Permeability

The entry and exit of water into and out of the plant cells is due to a phenomenon called **permeability** of the plasma membrane. The plasma membrane is considered to be selectively permeable because it allows the solvent, water and a few selected molecules and ions to pass through it.

Water Potential

The plant being a multiphase system, here the movement of water is expressed in terms of free energy. Water will flow from a region of higher free energy to a region of lower free energy. Free energy is the thermodynamic parameter which determines the direction along which physical and chemical changes should occur and may be defined as the sum of the energy of a system capable of doing work.

Based on free energy, water potential may be defined as the difference between the free energy of water molecules in pure water and the free energy of water in any other system (eg) water in a solution or water contained in the plant cell. Water potential is denoted by the Greek letter *psi* Ψ and is measured in bars. Thus, water potential is the chemical potential of water. The water potential of pure water is zero bar and water potential in a plant tissue is always less than zero bar and hence a negative number.

Table 5.1. Differences between diffusion and osmosis

Diffusion	Osmosis
Movement of solid, liquid or gas molecules from a region of higher concentration to a region of lower concentration	Movement of solvent molecules from a region of higher solvent concentration to a region of lower solvent concentration.
A selectively permeable membrane is not involved	Takes place through a selectively permeable membrane

Components of Water Potential

When a typical plant cell containing cell wall, vacuole and cytoplasm is placed in a medium containing pure water, there are a number of factors which determine the water potential of the cell sap. These are called the components of water potential and are named as

i. Matric potential, ii. Solute potential and iii. Pressure potential

Matric Potential

The term 'matric' is used for surfaces which can absorb water such as cell walls, protoplast and soil particles. Matric potential is the component influenced by presence of a matric and possesses a negative value and denoted as Ψ_m.

Solute Potential

It is a component of water potential which is also called Osmotic potential which represents the amount of solute present and is denoted as Ψ_s. Ψ_s of pure water is zero and so Ψ_s values are negative.

Pressure Potential

The cell wall exerts a pressure on the cellular contents inwards called **wall pressure** causing a hydrostatic pressure to be exerted in the vacuole called **turgor pressure** which is equal and opposite to wall pressure. Pressure potential which is denoted as Ψ_p is equivalent to either the wall pressure or turgor pressure. Water potential $\Psi = \Psi_m + \Psi_s + \Psi_p$.

Table 5.2. Differences between Diffusion Pressure Deficit and Water Potential

Diffusion Pressure Deficit (DPD)	Water Potential
1. DPD was originally called suction pressure	It is called Ψ_w where Ψ is psi and the chemical potential of water equivalent to DPD with a negative sign
2. It is measured in atmospheres.	It is measured in bars.
3. DPD is the difference between the diffusion pressure of a solution and pure solvent.	Water potential is the difference between free energy of water molecules in pure water and solution.
4. DPD = OP – TP where OP = Osmotic pressure and TP = Turgor pressure.	$\Psi_w = \Psi_m + \Psi_s + \Psi_p$ where Ψ_m = Matric potential ; Ψ_s = Solute potential ; Ψ_p = Pressure potential.
5. Water moves from lower DPD to higher DPD.	Water moves from higher water potential to lower water potential.

Water potential is thus the sum of the three potentials.

Thus the plant cell acts as an osmotic system having its own regulatory control over absorption and movement of water through the concerted effect of phenomena such as imbibition, diffusion and osmosis.

SELF EVALUATION

One Mark

Choose the correct answer

1. The protoplasm was considered as a polyphase colloidal system by
   a. Altmann b. Hemming c. Wilson Fisher d. Butschili
2. The movement of water into and out of cells is controlled by
   a. Water potential b. Endosmosis c. Exosmosis d. Plasmolysis
3. Flow of matter from a region of higher concentration to a region of lower concentration is called
   a. Imbibition b. Osmosis c. Diffusion d. Plasmolysis
4. The principle used in pickling is
   a. Imbibition b. Endosmosis c. Plasmolysis d. None of the above

Two Marks

1. Define: Tyndall effect / Brownian movement / Imbibition / Diffusion / DPD / Osmosis / Hypertonic solution / Hypotonic solution / Isotonic solution / Plasmolysis / Osmotic pressure / Turgor pressure / Wall pressure / Water potential / Permeability.

Five Marks

1. Why is the cell called a physiological unit?
2. Explain the physical nature of protoplasm.
3. Describe the properties of protoplasm.
4. Explain the components of water potential.
5. Explain plasmolysis and bring out its significance.
6. Differentiate between DPD and water potential.

Ten Marks

1. Explain osmosis with an experiment.
2. Write an essay on the physical nature and properties of protoplasm.

2. Water Transport

The water absorbed by the root hairs is translocated upwards through the xylem. The mystery of the upward movement of water is yet to be solved in a satisfactory way. The upward transport of water in plants which are 400 feet high has not been satisfactorily explained till date.

Though the mechanism for upward movement of water or **ascent of sap** is not clear, it has been proved that ascent of sap takes place through xylem.

The **girdling experiment** was done is a plant with thick stem where the outer layer of phloem was removed. Still it was found that ascent of sap continued to take place proving that ascent of sap takes place through the xylem.

A young tomato or balsam seedling was taken and kept in a beaker containing water coloured with eosin. After sometime it was seen that streaks of red colour were running up the stem. When a cross section of the stem was taken, it was found that xylem was coloured proving that ascent of sap takes place through the xylem tissue.

Mechanism of Ascent of sap

A number of theories have been put forward at various times to explain the mechanism of ascent of sap. These are (i) Vital theories, (ii) Root Pressure theory and (iii) Transpiration pull.

Vital Theories

These theories had been given very early and have only historical importance. **Godslewski** gave the **relay pump theory**. According to this theory the pumping of water takes place upwards due to the vital activities of xylem parenchyma and xylem rays.

J.C. Bose has put forward the **pulsation theory**. According to this theory water is pumped up due to the contraction and expansion of innermost cortical cells which creates a pulsation causing upward movement of water.

2.a. Transpiration Pull Theory

This is also called as **cohesion-tension theory** put forward by **Dixon** and **Joly** (1894) and supported by **Renner, Curtis** and **Clark**. This theory is based on a number of features.

Cohesion and Adhesion

Mutual attraction between water molecules is called **cohesion** and this force may have a value as high as 350 atmospheres.

The wall of the tracheids and vessels which transport water are made up of lignin and cellulose and have high affinity for water and this is called **adhesion**.

Xylem vessels have perforated end walls and form a tubular structure from roots to the shoot tip. This provides a continuous channel for movement of water which cannot be pulled away from xylem wall due to cohesive and adhesive properties.

Transpiration Pull

The transpiration taking place through leaves causes negative pressure or tension in xylem sap which is transmitted to the root. This is called **transpiration pull** which is responsible for the movement of water column upward.

Objections and Explanation

Air bubbles may enter the water column due to atmospheric pressure variations. Dixon explained that the water continuity is maintained by network of tracks of water due to interconnections between longitudinal vessels.

Septa in xylem vessels may check the flow of water. But the suction force or negative tension developed by transpiration pull is sufficient to overcome resistance developed by septa.

Experiment to Demonstrate Cohesion - Tension Theory

A young transpiring twig is fixed to a glass tube filled with water. The lower end of the tube is kept dipping in a dish containing mercury. As transpiration occurs in the twig the level of mercury rises in the tube due to the suction force created.

Instead of the transpiring twig, if a porous dry pot filled with water is used, the same results are got.

Thus the cohesion -

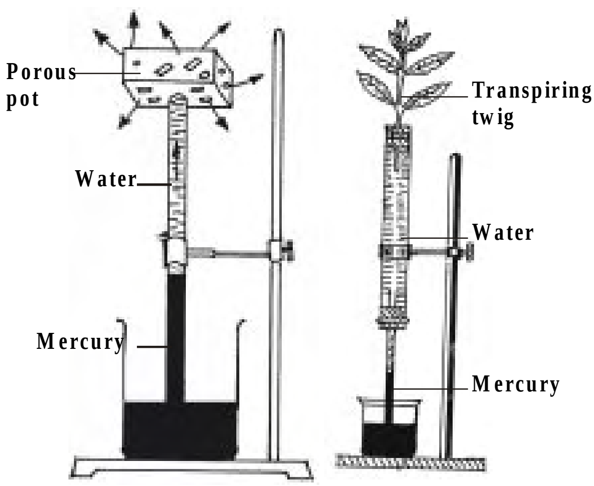


Fig : 5.5. Experiment to demonstrate transpiration pull

tension or transpiration pull theory best explains the ascent of sap as it stands today but still this theory is also not completely accepted.

2.b. Factors Affecting Rate of Transpiration

The process of transpiration is influenced by a number of factors which may be broadly classified as External factors and Internal factors.

External Factors

These include conditions of the environment which affect the rate of transpiration. The external factors are humidity, wind, atmospheric pressure, temperature, light and water.

Humidity

Humidity refers to the amount of water vapour present in the atmosphere. If humidity is high, rate of evaporation is low and so the rate of transpiration is slow.

Wind

Wind is air in motion which enhances the rate of evaporation. Wind increases the rate of transpiration. But winds at high velocity bring about closure of stomata and thus reduce the transpiration rate.

Atmospheric Pressure

Low atmospheric pressure increases the rate of transpiration. Water vapour from transpiring surfaces rapidly moves into the atmosphere which is at low pressure.

Temperature

Increase in temperature increases the rate of transpiration as high temperature causes the water in intercellular spaces to vaporize at a faster rate.

Light

Light influences opening of stomata and so rate of transpiration is high in light and less in darkness.

Water

Less amount of soil water decreases the rate of transpiration. If the rate of transpiration exceeds the rate of absorption, the stomata get closed the cells lose their turgidity and the plant wilts. If the plant regains the turgidity, it will regain its

original position and this is called **incipient wilting**. If the wilting is **irreversible** it is called **permanent wilting**.

Internal Factors

These are factors prevailing within the plant which are inherent properties of the plant itself and include leaf structure, root-shoot ratio and age of plants.

Leaf Structure

In xerophytes, the rate of transpiration is reduced due to structural modifications such as less surface area, thick cuticle with hard and leathery surface, leaf rolling, sunken stomata, waxy coating, lower stomatal frequency, hairy covering and development of mechanical tissue. In the case of the plants such as *Opuntia* and *Asparagus* the leaf is modified into thorns and the stem becomes flattened and green to perform the function of the leaf. Such a structure is called a **Cladode**.

Root - Shoot Ratio

Transpiration shows a direct relation with the amount of water absorbed by the roots and the water lost through leaves. Therefore the increase in the root-shoot ratio will also increase the rate of transpiration.

Age of Plants

Germinating seeds generally show a slow rate of transpiration. It increases with age and becomes maximum at maturity. But rate of transpiration decreases during senescence.

Plants absorb water through the root system and only 2% is needed by the plant for the various metabolic activities. The rest of the water is lost through the aerial parts of the plant by a process called **transpiration**.

The loss of water in the form of vapour from the aerial parts of the plant is referred to as **transpiration**.

Types of Transpiration

Transpiration in plants is essentially of three types.

a. Cuticular

b. Lenticular

c. Stomatal

a. Cuticular Transpiration

Cuticular transpiration takes place through outer covering of the epidermis called **cuticle** made up of substance called **cutin**. Only a very little part of transpiration takes place by this process.

b. Lenticular Transpiration

Lenticels are regions on the bark having loosely arranged cells called **complementary cells**. A very little amount of water is lost by transpiration through lenticels.

c. Stomatal Transpiration

Stomata are minute openings on the epidermis of leaves and stems. Most of the water lost by transpiration (about 95%) takes place through the stomata.

Structure of Stoma

A stoma is a minute pore on the epidermis of aerial parts of plants through which exchange of gases and transpiration takes place.

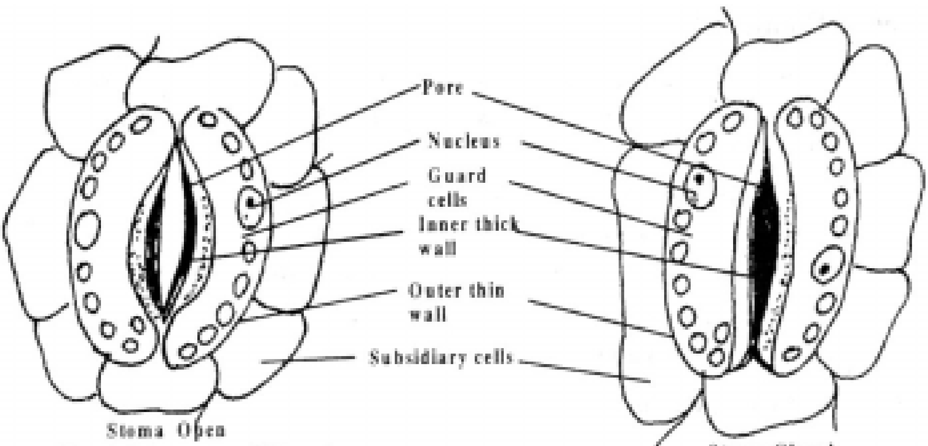


Fig : 5.6. Structure of Stomata

Each stoma is surrounded by a pair of kidney shaped **guard cells**. Each guard cell is a modified epidermal cell showing a prominent nucleus, cytoplasm and plastids. The wall of the guard cell is differentially thickened. The inner wall of each guard cell facing the stoma is concave and is thick and rigid. The outer wall is convex and is thin and elastic.

The guard cells are surrounded by a variable number of epidermal cells called **subsidiary cells**.

2.c. Mechanism of Stomatal Opening and Closing

Opening and closing of stomata takes place due to changes in turgor of guard cells. Generally stomata are open during the day and close at night.

The turgor changes in the guard cells are due to entry and exit of water into and out of the guard cells. During the **day**, water from subsidiary cells enters the guard cells making the guard cells fully turgid. As a result, the thin elastic convex outer walls are bulged out causing the thick and rigid concave inner walls to curve away from each other causing the stoma to open.

During **night** time, water from guard cells enters the subsidiary cells and as a result, the guard cells become flaccid due to decrease in turgor pressure. This causes the inner concave walls to straighten up and the stoma closes.

The actual mechanism responsible for entry and exit of water to and from the guard cells has been explained by several theories.

The most important theories are

i. The starch-sugar interconversion theory of Steward
ii. Active K^+ transport of Raschke
iii. pH theory of Scarth
iv. Proton-potassium pump theory of Levitt.

i. The Starch - Sugar interconversion Theory

Steward (1964) holds that during the day the enzyme **phosphorylase** converts starch to sugar, thus increasing osmotic potential of guard cells causing entry of water. The reverse reaction occurs at night bringing about closure.

Phosphorylase (day)

Starch $\rightleftharpoons$ Sugar

(stoma opens) night (stoma closes)

ii. Proton - Potassium Pump Hypothesis

Levit in 1974 combined the points in Scarth's and Steward's hypothesis and gave a modified version of the mechanism of stomatal movement which was called the **proton - potassium pump hypothesis**.

According to this hypothesis K^+ ions are transported into the guard cells in the presence of light. The sequence of events taking place are

i. Under the influence of light, protons formed by dissociation of malic acid move from cytoplasm in to the chloroplasts of guard cells.

ii. To counter the exit of protons, K^+ ions enter the guard cells from the surrounding mesophyll cells.

iii. K^+ ions react with the malate ions present in the guard cells to form potassium malate.

iv. Potassium malate causes increase in the osmotic potential of guard cells causing entry of water into the guard cells as a result of which the stoma opens.

v. At night the dissociation of potassium malate takes place and K^+ ions exit out of guard cells causing loss of water from guard cells and so the stoma closes

Noggle and Fritz (1976) supported this theory and gave a scheme for opening of stomata.

Light
↓
Starch
↓
Production of Malic acid
↓
Dissociation into H^+ and Malate
↓
Exit of H^+ and entry of K^+ ions
↓
Formation of Potassium malate
↓
Increase of OP of guard cells
↓
Entry of water into guard cells
↓
Increase in turgor of guard cells
↓
Stoma opens

This theory is the widely accepted one as Levitt was able to demonstrate rise in K^+ ion level during the day and the formation of organic acids like malic acid with the unused CO_2 present in the guard cells.

2.d. Factors Affecting Stomatal Movement

There are a number of factors which influence stomatal movements. These include light, temperature, potassium chloride, organic acid, carbondioxide concentration, water and abscissic acid.

Light

Light greatly influences the opening and closing of stomata as it stimulates production of malic acid due to conversion of starch to sugar. Stomata do not open in U-V light and green light but remain opened in the blue and red regions of the spectrum.

Temperature

Stomata open with rise in temperature and close at lower temperature as light and temperature are directly related. But higher temperatures also cause stomatal closure.

Potassium Chloride

Accumulation of potassium chloride causes opening of stomata.

Organic Acid

The increase of organic acid content in the guard cells causes the stomata to open.

Carbondioxide Concentration

Stomatal movement is influenced by the concentration of carbondioxide. At low concentrations of CO_2, the stomata open. With increase in the concentration of CO_2, the stomata begin to close and when CO_2 concentration of cells is higher than its concentration in the air, the stomata completely close.

Stomatal movement is always influenced by the CO_2 concentration of the intercellular spaces of the leaf and not the concentration of the air.

Water

Water is responsible for causing changes in the turgor of the guard cells. Guard cells become flaccid on losing water and so the stomata close. Similarly the guardcells become fully turgid on gaining water and the stomata open. Under conditions of water scarcity also, the stomata close.

Abscissic Acid

Abscissic acid accumulates in the leaves when the plants experience water stress or water deficit. It has been observed, that ABA (Abscissic acid) stimulates closure of stomata under these conditions.

SELF EVALUATION

One Mark

Choose the correct answer

1. During the day the guard cells experience
   a. exosmosis b. endosmosis c. fall in turgor d. loss of water

2. The starch - sugar interconversion theory was given by
   a. Steward b. Scarth c. Levitt d. Raschke
3. Scarth put forward the
   a. active K^+ transport theory b. pH theory
   c. starch-sugar interconversion theory d. proton-potassium pump hypothesis
4. The relay pump theory was put forward by
   a. Godslewski b. J.C.Bose c. Stocking d. Dixon
5. J.C. Bose gave the
   a. relay pump theory b. root pressure theory
   c. pulsation theory d. cohesion-tension theory
6. The term root pressure was coined by
   a. Stocking b. Stephan Hales c. Dixon d. J.C.Bose
7. Lignin and cellulose have affinity for water. This is called
   a. adhesion b. cohesion c. root pressure d. none of the above
8. The transpiration pull theory was supported by
   a. Renner b. Curtis c. Clark d. All the above

Two Marks

1. Define : Stomata / Transpiration / Starch - sugar interconversion.
2. Define : Root pressure / Transpiration pull / Cohesion / Vital theories.

Five Marks

1. Explain the mechanism of stomatal opening and closing.
2. Describe the Proton - potassium pump hypothesis.
3. Demonstrate root pressure with the help of an experiment.
4. Give an experiment to demonstrate cohesion - tension theory.
5. Explain the objections to the root pressure theory.
6. Give an account of the inherent properties of the leaf which affect the rate of transpiration.

Ten Marks

1. Written an essay on the theories explaining mechanism of stomatal movement.
2. Give an account of the factors influencing stomatal movement.
3. Explain the postulates of the cohesion - tension theory. Add a note on the objections and explanation.
4. List and explain the factors affecting transpiration.
5. Give an account of the various theories explaining the ascent of sap.

3. Mineral Nutrition

Mineral nutrition of plants was a phenomenon known from very ancient times. **Woodward** (1699) observed for the first time that plants grow better in muddy water than rain water. Later it was proved that minerals have specific functions in plant metabolism.

When an oven-dried plant material is ignited at 400-600°C, all the organic materials are oxidized and incombustible matter remains as plant ash. When this ash was analysed it was found to contain 40 elements besides C,H,O,N and S which were oxidized. All these are not essential for plant nutrition but on analysis the important essential elements have been identified and based on their role in plant metabolism and requirement, they have been classified as major elements and trace elements.

The functions of the various minerals in general depends on the role of the mineral in plant metabolism.

Criteria for Essentiality of a Mineral Element

Essential elements should have the following characteristics

i. Normal growth and reproduction must be dependent on particular mineral elements.

ii. An essential element must have direct influence on the plant.

iii. Essential elements must be indispensable and their substitution by other elements must be impossible.

iv. Some elements are required in very low quantities and the status of essentiality or non essentiality is doubtful. For example **silicon.**

3.a.Functions of Minerals

i) Mineral elements are constituents of the various parts of plant body, for example calcium which is found in the middle lamella, nitrogen and sulphur in proteins, phosphorus in nucleic acids.

ii) The mineral elements influence the osmotic pressure of the plant cell.

iii) The mineral elements absorbed from the soil affect the pH of the cell sap.

iv) Elements like Fe, Cu, Mn and Zn act as catalysts in various enzymatic processes.

v) Elements like Ca, Mg, Na and K or their salts neutralize the toxic effects of other elements in the cell.

vi) Elements like As, Cu, and Hg show toxic effects at certain stages of the plant.

vii) Deposition of ions like K^+ and Ca^{++} on cell membrane change its permeability.

Hydroponics

The term **hydroponics** has been used for growth of plants in water culture. This may also be referred to as **soil-less agriculture, test-tube farming, tank farming** or **chemical gardening.**

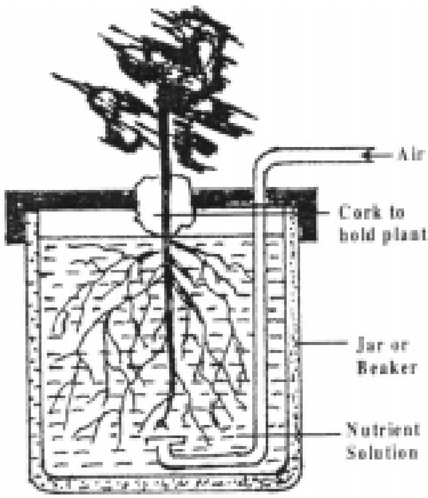


Fig : 5.7. Hydroponics

Commercially hydroponic cultures are maintained in large shallow concrete, cement wood or metal tanks in which gravel and nutrient solutions are taken. The tanks are provided with pumps and empty auxiliary tanks to pump out and circulate the growth solution and to maintain proper aeration of the nutrient solution.

The technique of hydroponics is employed to know which mineral element is essential for the growth and development of the plant. Commercially the application of hydroponics involve the production of **horticultural** and **floricultural** crops. This method may be used to increase yield of ornamentals such as gladioli, snapdragon, roses and vegetables such as carrot, radish, potatoes, tomatoes and lettuce.

Advantages of Hydroponics

i. It is possible to provide the desired nutrient environment.
ii. The acid-base balance can be easily maintained.
iii. Mulching, changing of soil and weeding are eliminated.
iv. Proper aeration of nutrient solution is possible.
v. Labour for watering of plants can be avoided.
vi. Tilling is not necessary.

Disadvantages of Hydroponics

i. Production is limited when compared to field conditions.
ii. Technical skill is required to design equipment.
iii. If a disease appears all plants in the container will be affected.
iv. Can be used only for short duration.

3.b.Essential Major Elements and Trace Elements

The plant ash reveals the presence of 40 elements but all are not essential for plant nutrition, only a few are essential for growth and development of plants. These are called the **essential elements**. The essential elements may be grouped as **major elements** or **macronutrients** and **trace elements** or **micro nutrients,** based on their requirement by plants.

Major elements or Macro Nutrients

These elements are required in large amounts and form the plant consituents. The major elements are otherwise known as **macronutrients**. These include **carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium** and **sulphur.** These elements form an integral part of complex organic molecules. Some of these elements help in the functioning of enzyme systems. The sources of macronutrients are generally the soil or the atmosphere. **Carbon** is got from carbodioxide of the atmosphere. **Oxygen** is derived from water and atmospheric oxygen. **Nitrogen** is present in the atmosphere as an inert substance which is brought to the soil and converted to soluble nitrates either by asymbiotic or symbiotic nitrogen fixation. **Phosphorous** and **sulphur** and derived from rocks during weathering. The source of **hydrogen** is water.

Trace elements or Micronutrients

Elements like **iron, boron, managanese, copper, zinc** and **molybdenum** are required for plants only in very small amounts but these are indispensable for the normal growth and development of plants.

3.c.Physiological Role and Deficiency Symptoms of Mineral Elements

Macro Nutrients

1. Carbon, hydrogen and oxygen

These are not mineral elements in the true sense but have been included because these elements form the composition of all organic compounds present in

plants. They are a part of carbohydrates, proteins, and fats. Thus these elements have a role to play in the general metabolism of plants.

Deficiency symptoms

Deficiency of these elements is very rare because the plants have a steady supply of these through water and gaseous exchange. Deficiency affects the normal growth and developments of plants.

2. Nitrogen

Nitrogen is an essential constituent of proteins, nucleic acids, vitamins and many other organic molecules such as chlorophyII. Nitrogen also forms a constitutent of various hormones, coenzymes and ATP.

Deficiency symptoms

i) Stunted growth
ii) Chlorosis
iii) Reduction in flowering
iv) Excessive colouring in apple and peach and reduction in fruit size.
v) Decrease in protein contents
vi) Change in the pigmentation pattern

3. Phosphorus

It is present in plasma membrane, nucleic acids, nucleotides, many co-enzymes and organic molecules. It plays an important role in energy metabolism. Phosphorus promotes healthy root growth and fruit ripening.

Deficiency symptoms

i. Loss of older leaves
ii. Reduction in growth
iii. Increase in phosphatase enzyme activity
iv. Causes accumulation of carbohydrates in soyabean

4. Potassium

Potassium is required in the meristematic regions and regions of cell differentiation. It accumulates in older leaves. Though it does not have a structural role, it is involved in stomatal opening and closing. It is an activator of many enzymes and has a role in protein and carbohydrate metabolism.

Deficiency symptoms

i. Leaf tips curve downward

ii. Causes mottled chlorosis

iii. Development of chlorosis at tips and margins of leaves.

iv. Shortening of internodes and stunted growth.

5. Sulphur

Sulphur is the constituent of certain vitamins such as **thiamine** and **biotin.** It is constituent of **coenzyme - A** playing an important role in respiration. It forms the sulphydryI group in many enzymes and is a constitutent of sulphur containing aminoacids such a **cystine, cysteine** and **methionine.**

Deficiency symptoms

i. Causes inhibition of protein synthesis.

ii. Younger leaves show chlorosis first

iii. Chloroplasts of mesophyII show a decrease in stroma lamellae but grana increase.

6. Magnesium

Magnesium is a constituent of chlorophyII molecule which cannot be formed without magnesium. It has a vital role in carbohydrate metabolism and the binding of ribosomal sub-units. Magnesium is the activator of many enzymes involved in DNA and RNA synthesis. It acts as a phophours carrier and activates enzymes such as PEP carboxylase and RuBP carboxylase.

Deficiency symptoms

i. Interveinal chlorosis takes place.

ii. Anthocyanin pigment deposition takes place after chlorosis.

iii. Necrotic spots appear in acute cases.

7. Calcium

Calcium forms an important constituent of the cell wall occurring in the middle lamella as calcium pectate. It has an important role in the formation of plasma membrane. Calcium plays a role in mitotic cell division and is a constitutent of enzymes like **phospholipase** and **adenyl kinase** where it acts as an activator.

Deficiency symptoms

i. Affects the carbohydrate metabolism.

ii. The process of respiration is badly affected as number of mitochondria are decreased.

iii. Meristematic tissues are affected and leaf and root tips die.

iv. Cell wall may become brittle or rigid.

Micro Nutrients

8. Iron

Soil is generally not deficient in iron. Iron is a constituent of various flavoproteins and forms a part of enzymes such as **catalases, peroxidases** and **cytochromes.** It plays an important role in the electron transport system of photosynthesis being part of cytochrome and ferredoxin.

Deficiency symptoms

i. Causes interveinal chlorosis and the leaves become yellow or white.

ii. Impairs aerobic respiration and related processes.

iii. Fruit trees particularly show sensitivity to iron deficiency.

9. Boron

Leaves and seeds require boron. It is necessary for uptake and utilisation of Ca^{++} ions, pollen germination, cell differentiation and translocation of carbohydrates. It plays a role in nitrogen metabolism, hormone and fat metabolism.

Deficiency symptoms

i. It causes **brown heart-rot disease** in beetroots.

ii. In apple internal tissues become corky.

iii. Causes leaf to curl and become brittle.

iv. Premature fall of fruits and flowers.

10. Managanese

Managanese is required by leaves and seeds. It is an activator of enzymes like **carboxylases, oxidases, dehydrogenses** and **kinases.**

Deficiency symptoms

i. Causes **grey spot disease** in oat.

ii. Poor development of root system.

iii. Interveinal chlorosis occurs.

11. Copper

This is required in all plant parts. Copper forms a component of enzymes such as phenolases and tyrosinase. Copper being a constituent of plastocyanin plays a role in photophosphorylation. Copper maintains the carbohydrate - nitrogen balance.

Deficiency symptoms

i. Causes **die back of shoots** especially in *Citrus*.

ii. A disease called **'exanthema'** causes the yield of gums on the bark.

iii. **Reclamation disease** is caused in plants growing on newly reclaimed soil where seed formation is affected.

12. Zinc

Zinc is involved in the synthesis of indole acetic acid by activating the enzyme **tryptophan synthetase.** It plays a role in protein synthesis. It acts as an activator of many other enzymes such as **carbonic anhydrase, alcohol dehydrogenase, hexokinase** and so on.

Deficiency symptoms

i. Causes distortion of growth.

ii. Leaves become very small and rosetted called as **little leaf disease.**

iii. Interveinal chlorosis and stunted growth of stems is seen.

13. Molybdenum

Molybdenum has an important role to play in the **metabolism of nitrogen.** It affects the synthesis of ascorbic acid. It activates the enzymes involved in nitrogen metabolism.

Deficiency symptoms

i. It leads to mottling and wilting of leaves at the margins causing **"yellow spot" disease** of *Citrus*.

ii. **"Whiptail" disease** in cauliflowers causing narrowing of leaf blades and their rugged appearance due to distortion.

Table 5.3. Physiological Role and Deficiency Symptoms of important Mineral Elements

Sl. No.	Element	Physiological Role	Deficiency Symptoms
1. 2. 3.	**Carbon** **Hydrogen** **Oxygen**	General metabolism of plants	Affect normal growth and development.
4.	**Nitrogen**	Constituent of proteins, nucleic acids, coenzymes and ATP.	Chlorosis, stunted growth and reduction in flowering.
5.	**Phosphorus**	Constituent of plasma membrane, coenzymes and nucleotides.	Reduction in growth, increase of phosphatase activity.
6.	**Potassium**	Required in meristematic regions and in stomatal movement	Mottled chlorosis, shortening of internodes.
7.	**Sulphur**	Constituent of thiamine and biotin coenzyme-A, cystine and cysteine.	Inhibition of protein synthesis and chlorosis of young leaves.
8.	**Magnesium**	Constituent of chlorophyll, activator of PEP and RuBP carboxylases.	Intervenial chlorosis and deposition of anthocyanin pigments.
9.	**Calcium**	Constituent of cell wall and plasma membrane, helping in mitosis.	Carbohydrate metabolism affected, meristematic tissues affected.
10.	**Iron**	Constituent of flavo proteins, catalases, peroxidases and cytochromes.	Sensitivity in fruit trees, interveinal chlorosis, impairs aerobic respiration.
11.	**Boron**	Necessary for uptake and utilisation of Ca^{2+}, pollen germination and translocation of carbohydrates.	Brown heart rot disease in beetroot, corkiness of internal tissues of apple, premature fall of fruits and flowers.
12.	**Manganese**	Required by seeds and leaves, activating enzymes like oxidase, carboxylase and kinase.	Grey spot disease in oats, poor development of root system.
13.	**Copper**	Component of enzymes like phenolase, tyrosinase and plastocyanin.	Die back of shoots in *Citrus*, Exanthema-producing gums on bark, Reclamation disease - affecting seed formation.
14.	**Zinc**	Activates enzymes like tryptophan, synthetase, carbonic anhydrase and alcohol dehydrogenase.	Rosetted leaves causing little leaf disease, stunted growth of stems.
15.	**Molybdenum**	Plays a role in nitrogen metabolism and synthesis of ascorbic acid.	Yellow spot disease of *Citrus*, Whiptail disease in cauliflowers causing narrowing of leaf blades.

Self Evaluation

One Mark

Choose the Correct Answer

1. Hydroponics is otherwise called
   (a) soil-less agriculture (b) tank farming
   (c) chemical gardening (d) all the above

2. This element is a constituent of chlorophy11
   (a) Manganese (b) Magnesium
   (c) Potassium (d) Zinc

Fill in the blanks

1. Exanthema is a disease caused due to deficiency of ....
2. Deficiency of Molybdenum causes...............of cauliflower
3. Sulphur containing amino acids are..........and ....

Match

Boron	-	Thiamine
Sulphur	-	Reclamation
Copper	-	Stomatal Movements
Potassium	-	Translocation of Carbohydrates

Two Marks

1. Define Hydroponics/Exanthema/Reclamation

Five Marks

1. Explain the advantages and disadvantages of Hydroponics.
2. Describe the technique of hydroponics with a diagram.
3. Describe the criteria for essentiality of an element.
4. Explain the role and deficiency symptoms of any three macronutrients.
5. Describe the deficiency symptoms of copper, boron and molybdenum.

Ten Marks

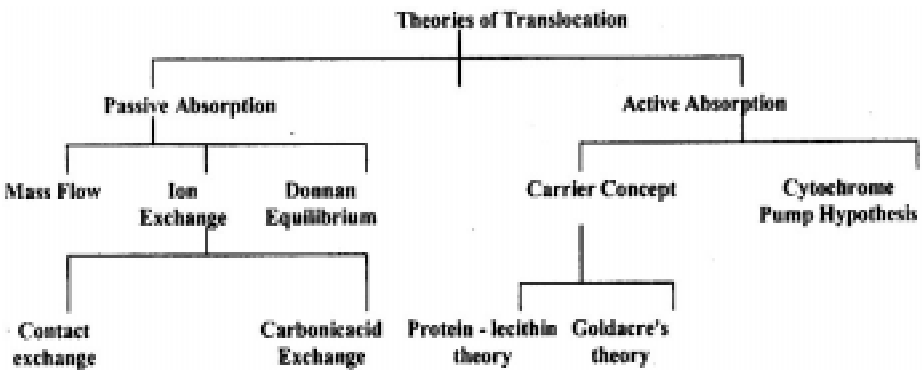
1. Write an essay on the role and deficiency of macro and micronutrients.

3.d.Theories of Translocation

Plants absorb minerals from the soil and translocate them to other parts of the body. Minerals are absorbed in the form of **soil solution** contained in the pore spaces between the soil particles and the root hair. The soil solution contains the mineral salts in the dissolved state. Several theories have been put forth to explain the mechanism of translocation of mineral salts. These theories can be placed under two headings (i) **Passive absorption** and (ii) **Active Absorption** which can be further subdivided as follows.

i. Passive Absorption

When the movement of mineral ions into the roots occurs by diffusion without any expenditure of energy in the form of ATP it is called **Passive Absorption.** This form of absorption is not affected by temperature and metabolic inhibitors. Rapid uptake of ions is observed when a plant tissue is transferred from a medium of low concentration to a medium high concentration. Various theories have been put forward to explain mineral salt uptake by passive absorption.



(a) Ion exchange theory

Mineral elements are absorbed in the form of ions. The anions and cations within the plant cells are exchanged with the anions and cations of equivalent charge from the external medium in which the cells are kept. This mechanism can be explained by two theories.

(i) Contact exchange theory

This was put forward by Jenny and Overstreet (1939). According to this theory ions are transferred from soil particles to root or *vice versa* without passing into solution. The ions are electrostatically adsorbed to surface of root cells or

clay particles and held tightly. These ions oscillate within a small volume of space called **oscillation volume.** when the oscillation volume of two ions of same charge overlap, one is exchanged for the other. this is called **contact exchange.**

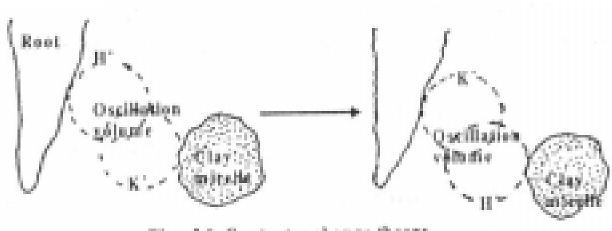


Fig : 5.8. Contact exchange theory

(ii) Carbonic acid exchange theory

According to this theory the soil solution plays an important role in exchange of ions by providing a medium. CO_2 released during respiration combines with water to form **carbonic acid** (H_2CO_3) which dissociates as H^+ (Hydrogen ions) and **HCO_3** (bicarbonate ions). A cation adsorbed on clay micelle may be exchanged with the H^+ of soil solution and this cation diffuses into the root in exchange for H^+ion.

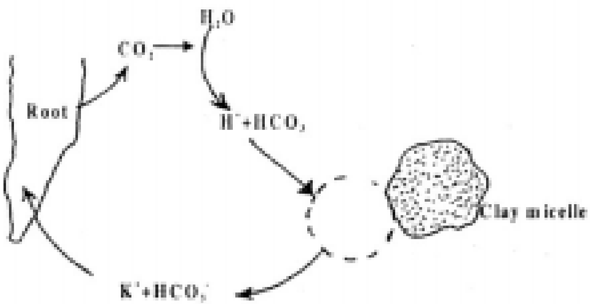


Fig : 5.9. Carbonic acid exchange theory

(b) Donnan Equilibrium

This was proposed by **F.G.Donnan** in which the **fixed** or **indiffusible** ions play an important role. These ions are present on the inner side of the cell and cannot diffuse out. When a cell having fixed anions is immersed in sals solution, anions equal in number and charge to the fixed ions move into the cell. To balance the negative charges of the fixed ions additional cations also move into the cell and the cell sap cation concentration becomes higher than the external medium. This is called **Donnan Equilibrium.**

In the same way if there are fixed cations, additional anions will accumulate from the external medium.

II. Active Absorption

The absorption of ions against the concentration gradient with the expenditure of metabolic energy is called **active absorption.** In plants, the vacuolar sap shows accumulation of anions and cations against the concentration gradient which cannot

be explained by the theories of passive absorption. The mechanism of active absorption of salts can be explained by several theories.

(a) Carrier Concept

The cell shows the presence of **Carriers** or **transporters** which are highly specific for a particular ion. The carrier picks up an ion from external medium to form a carrier-ion complex, undergoes rotation at 180°, moves across the membrane and releases the ions on the inner side of membrane and returns to pick up another ion. The carrier may be an enzyme or a protein. Metabolic energy is expended in this process. This concept is supported by **Isotopic exchange** using radioactive isotopes, **saturation effect** and **specificity of carriers.** The carrier concept is explained by two theories:

(i) Protein-Lecithin as carrier
(ii) Goldacre's theory

Protein - Lecithin as carrier

Bennet - Clark proposed that the carrier can be a protein associated with a phosphatide e.g. Lecithin which carries both anions and cations and forms a **lecithin-ion complex**. this moves to the inner side of membrane, releases the ion by hydrolysis forming phosphatidic acid and choline due to the action of the enzyme **lecithinase.** Lecithin is regenerated with the help of enzymes **Choline esterase** and **choline acetylase.** This requires expenditure of metabolic energy.

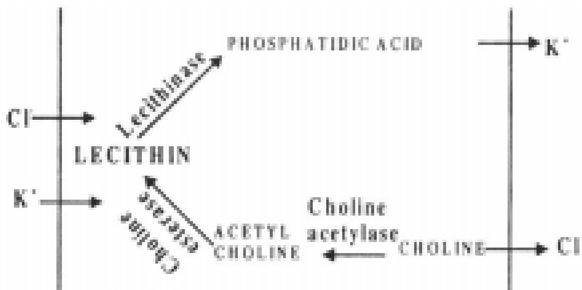


Fig : 5.10. Protein - Lecithin as carrier

(b) Cytochrome Pump Theory or Electron Transport Theory

This theory was proposed by H.Lundegardh (1954) who suggested that anions could be transported across the membranes by cytochrome system utilising energy released by direct oxidation of respiratory intermediates.

The important postulates are:

i) Only anions can be actively transported.

ii) Cytochromes act as carriers in absorbing anions.

iii) Oxygen gradient helps in oxidation at outer surface and reduction at the inner surface.

iv) Transport of cations can be along the electrical gradient created by ion accumulation.

v) Selectivity in ion absorption cannot be explained and

vi) this is absent in plants respiring anaerobically.

Therefore this theory explains respiration due to anion absorption which was called **anion respiration** or **salt respiration.**

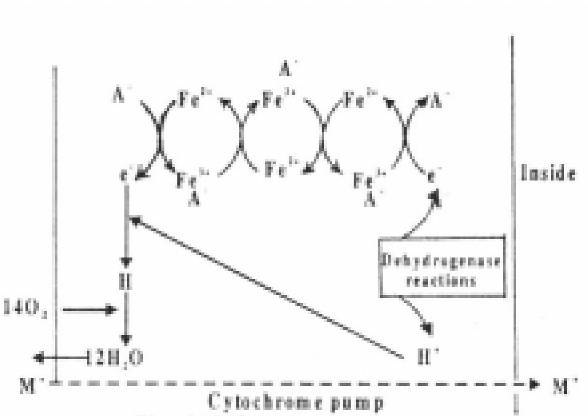


Fig : 5.11. Cytochrome pump

3.e.Translocation of Solutes

In higher plants food is synthesised only in the green leaves which are the sites of Photosynthesis. From here the food is traslocated to the different parts of the plant in the soluble form. the process by which the synthesized food from the leaves is translocated to the different parts of the plant depending on their requirement is called **translocation of food.** the food materials in excess than the required amount are stored in insoluble form in the various storage organs and are translocated in solution or soluble form. Therefore thisis also referred to as translocation of solutes.

Direction of translocation

Translocation of food occurs in the downward upward and lateral directions.

Down ward translocation

Downward trnaslocation takes place from the leaves downwards to the stem, roots and storage organs.

Upward translocation

In some stages of plant life such as seed germination, emergence of new shoots from underground storage organs and development of buds, flowers and fruits, the food materials are translocated upward.

Lateral translocation

In certain parts of stem and roots food is translocated in lateral direction through medullary rays.

Ringing experiment to demonstrate downward translocation

Take a plant and remove all the tissues outerto xylem and pith in the form of ring at any place on the stem. The portion from where tissues are removed is sealed with melted wax. After 7 or 8 days the epidermis and cortex of upper portion of the ring become very much swollen and from this swollen part the adventitious roots emerge out. It happens because the food material translocated from the leaves does not pase through the ring and is stored in the upper portion.

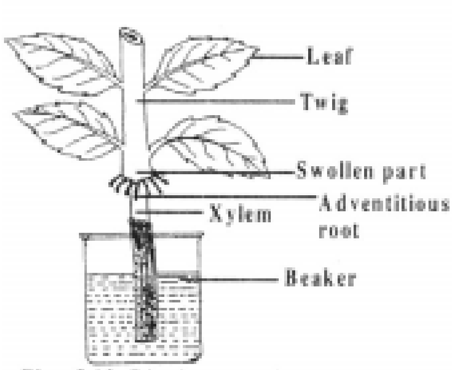


Fig : 5.12. Ringing experiment

Mechanism of Translocation

Following theories were proposed to explain the mechanism of translocation of solutes.

Munch's "Mass Flow" Hypothesis

A few scientists believe that the soluble food material in the phloem move just like the blood which moves in the blood vessels. Based on this Munch in 1930 proposed a hypothesis according to which the soluble food materials in the phloem show mass flow. The fundamental idea behind this hypothesis is that the sugars synthesized by mesophyll cells of leaves increase the osmotic pressure (OP) of these cells causing entry of water into mesophyll due to absorption of water by the xylem cells of root. In other words a turgor pressure gradient exists through phloem, between the source which is the mesophyll cell and the sink which refers to regions of requirement.

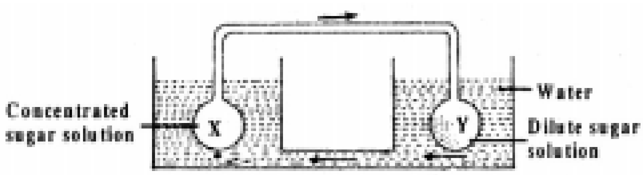


Fig : 5.13. Mass flow hypothesis

As a result, the turgor pressure of mesophyll cells increases on the upper side which forces the solutes dissolved in water to flow en masse into the phloem of stem and finally into the roots.

This can be explained by a physical system. It consists of a glass tube bent at right angles. At the two ends differentially permeable membranes are tied. thus there are two osmometers x and y.

The osmometer x has concentrated sugar solution while y has dilute sugar solution. The two osmometers are kept in two separate water containers connected with each other through a tube.

Osmosis will take place and water enters both the osmometers x and y but the water entering ‘x’ is more and as a result of turgor pressure developed, water will move out of x and will enter y. Here the solute molecules are carried to y en masse with the flow of water explaining Munch’s hypothesis.

The most important objection for this hypothesis is that it explains only unidirectional flow of solutes.

Importance of Munch’s hupothesis

This forms basis of the principle of phloem loading and unloading.

Phloem loading is caused by movement of photosynthates from mesophyll to phloem. Unloading of phloem is caused by movement of photosynthates from phloem to other parts where required. This is the source-sink relationship.

3.f. Nitrogen Metabolism

Nitrogen is an inert gas which constitutes 78% of the atmosphere. It is an important mineral present in the bodies olf living organisms. It forms a component of proteins and aminoacids and is also present in nucleic acids, cytochromes, chlorophyll, vitamins, alkaloids and so on.

Nitrogen cannot be used directly and is converted to Nitrites, Nitrates and Ammonia by a process called Nitrogen Fixation. There are many free living organisms like bacteria and blue-green algae which are involved in nitrogen fixation. The ammonia and urea present in the soil are directly absorbed by plants.

Nitrogen Cycle

The atmosphere is the source of elemental nitrogen which cannot be used directly by plants. The atmospheric nitrogen is converted to ammonia, nitrite, nitrate or organic nitrogen in the soil.

The death and decay of organic systems causes cycling of ammonia from amino acids, purnies and pyrimidines. Some of these forms may also be converted to Nitrogen gas and may be cycled back into the atmosphere.

The process by which these forms get inter converted to maintain a constant amount of nitrogen in atmosphere, by physical and biological processes is called **nitrogen cycle.** the cycle includes 5 stages.

i. Ammonification
ii. Nitrification
iii. Nitrate assimilation
iv. Denitrification and
v. Nitrogen fixation

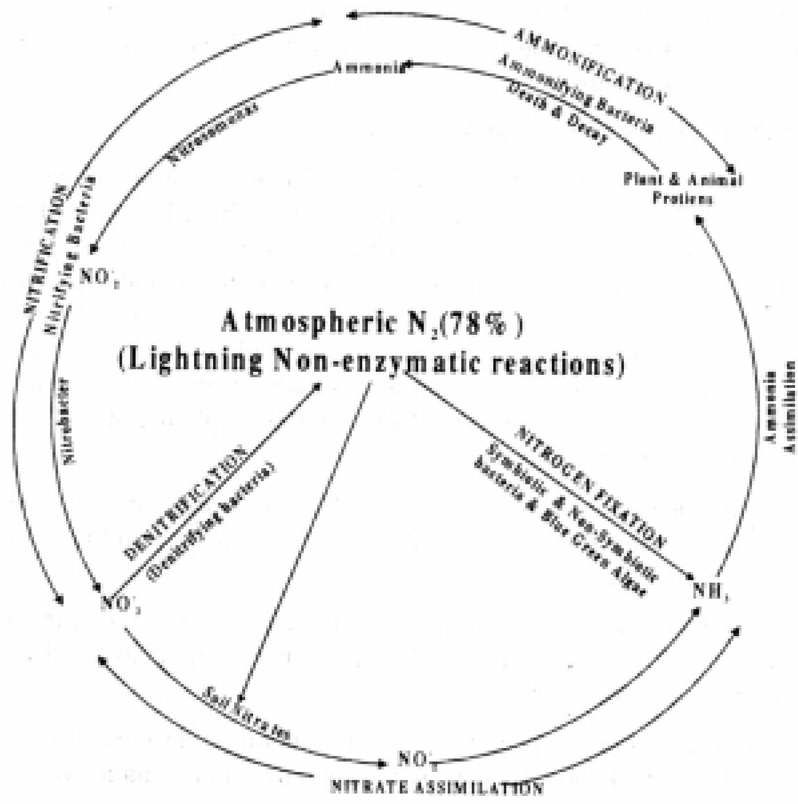


Fig : 5.14. Nitrogen Cycle

(i) Ammonification

This involves conversion of organic nitrogen to ammonium ions by microbes present in the soil. The sources of organic nitrogen in the soil are animal excreta and dead and decaying plant and animal remains which are acted upon by ammonifying saprotrophic bacteria such as ***Bacillus ramosus, Bacillus vulgaris,*** certain soil fungi and actinomycetes.

(ii) Nitrification

$$\textbf{Ammonia} \xrightarrow{\textbf{\textit{Nitrosomonas}}} \underset{\textbf{Nitrite}}{\mathbf{NO_2}} \xrightarrow{\textbf{\textit{Nitrobacter}}} \textbf{Nitrate}$$

In warm moist soils having a temperature of 30-35°C and neutral pH, ammonia gets oxidized to nitrite (NO_2-) and then nitrate (NO_{3-}) by the process of nitrification. Nitrifying bacteria like Nitrosomonas convert ammonia to nitrite and another bacterium called Nitrobacter converts nitrite to nitrate.

(iii) Nitrate Assimilation

$$\underset{\textbf{Nitrate}}{NO_3^-} \xrightarrow[\substack{\text{NAD(P)H} \\ \text{Nitrate} \\ \text{reductase}}]{2e^-} NO_2^- \xrightarrow[\substack{\text{Fd(red)} \\ \text{Nitrite} \\ \text{reductase}}]{6e^-} \underset{\textbf{Ammonia}}{NH_3}$$

The nitrate present in the soil is absorbed by plants through the root system in the form of NO_3-ions. But is cannot be used by plants directly. So it is first reduced to nitrite by the enzyme **nitrate reductase.** Nitrite is then converted to Ammonia by the enzyme **nitrite reductase** series of steps requiring a total of eight electrons provided by reduced NAD and Ferredoxin (Fd). This reduction of Nitrate of Ammonia and its incorporation into cellular proteins by aerobic micro organisms and higher plants is called **nitrate assimilation.**

(iv) Dentrification

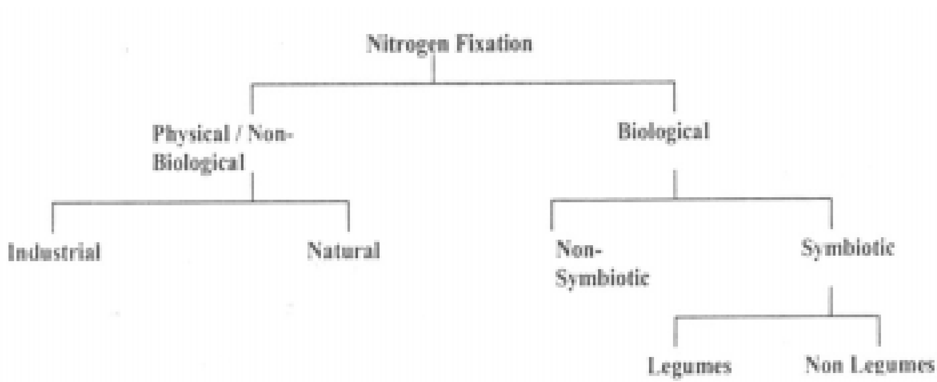
The process of conversion of nitrate and nitrite into ammonia, nitrogen gas and nitrous oxide (N_2O) is called **denitrification.** This process ends in the release of gaseous nitrogen into the atmosphere and thus completes the nitrogen cycle. A number of bacteria such as Pseudomonas denitrificans, Bacillus subtilis and Thiobacillus dentrificans are involved in this process.

(v) Nitrogen fixation

Nitrogen fixation refers to the conversion of elementary dinitrogen (N≡N) into organic form to make it available for plants. Nitrogen fixation is essentially of two types-

(i) Non-Biological or Physical and

(ii) Biological Nitrogen Fixation



Non-Biological or Physical Nitrogen Fixation]

This involves fixation of nitrogen by chemical process in industry or naturally by electrical discharges such as lightning.

Biological Nitrogen Fixation

Nitrogen fixation that takes place by living things is called biological nitrogen fixation. These include some bacteria and blue-green algae, which have acquired the capaicity to fix atmospheric nitrogen during the evolutionary process by possessing a set of genes called **'nif '** (Nitrogen fixing) genes. They fix Nitrogen as given in the following reaction.

$$N_2 \xrightarrow[\text{Fd(red) / NADPH}]{(6e^-)} NH_3$$
$$\text{Nitrogenase}$$

These organisms may be freeliving which are otherwise called **non-symbiotic nitrogen fixers** and may form symbiotic associations in some plants when they are called **symbiotic nitrogen fixers.**

Non-Symbiotic Nitrogen Fixation

This is carried out by free living organisms in the soilsuch as Bacteria, blue green algae.

Bacteria include aerobic bacteria such as *Azotobacter* and anaerobic baceria such as *Clostridium*, *Chlorobium* and *Chromatium*.

Blue green algae include *Chroococcus*, *Rivularia*, *Anabaena*, *Tolypothrix* and *Nostoc*.

These organisms contain an enzyme system called **Nitrogenase** which is a Mo-Fe (Molybdenum-ferredoxin) protein. this progressively reduces the dinitrogen molecules to form ammonia, with the help of Ferredoxin and energy from ATP.

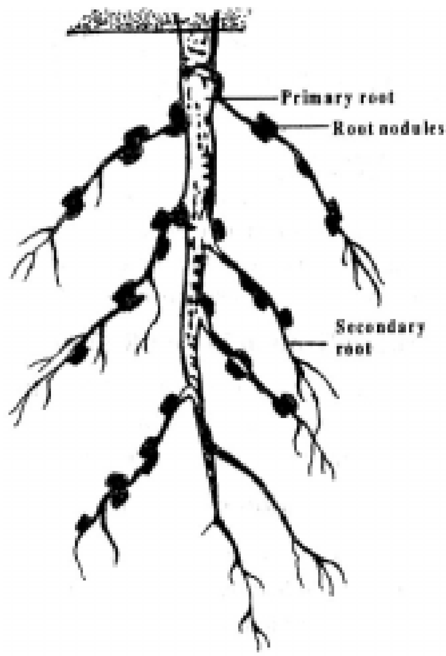


Fig : 5.15. Nodulated root

Symbiotic Nitrogen Fixation

This involves nitrogen fixation by micro organisms living in symbiotic association with higher plants which are commonly legumes, but non-legumes may also be involved. A symbiotic association is a mutually beneficial relationship between two living organisms which are called **symbionts.**

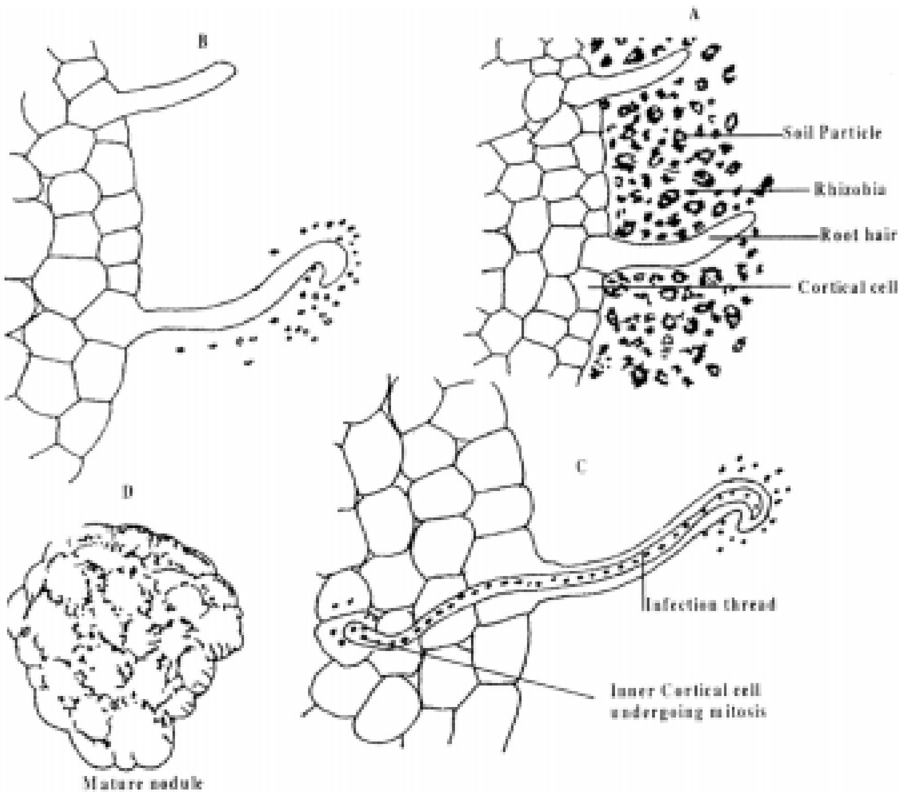


Fig : 5.16. Mode of development of root nodule

Nitrogen fixation in non-legumes

An actinomycete like *Frankia* establishes a symbiotic relationship with roots of higher plants such as casuarina and *Alnus*. Blue-green algae like *Nostoc* establish symbiotic relationships in the corolloid roots of *Cycas*, or thalli of *Anthoceros*.

Nitrogen fixation in legumes

This is the commonest type of symbiotic nitrogen fixation which has been elaborately studied. A soil bacterium called *Rhizobium* infects roots of leguminous plants (belonging to Family Leguminosae) and forms the root nodules.

These are involved in nitrogen fixation. The bacteria living in the soil enter the root hair and penetrate the root cortex through an infection thread. When the bacteria enter the cortical cells of roots, the latter get stimulated to divide vigorously and form nodules on the root. The bacteria come to occupy the nodules, and at this stage lacl a rigid cell wall being called **bacteroids.** These make use of the food substances of the root cells and secrete a pinkish pigment called **leghemoglobin** which is an oxygen carrier like hemoglobin.

The Rhizobia in the form of bacteroides contain the enzyme **nitrogenase** which is responsible for fixation of Nitrogen thus benefitting the host plant. Leghemoglobin is supposed to protect the nitrogenase enzyme as it can function only under anaerobic conditions.

Table 5.4. Major Nitrogen-fixing Biological Systems.

I. Free-Living (asymbiotic) microorganisms		
Bacteria		
Aerobic,	Species of *Azotobacter*	
Aerobic, non-photosynthetic	Species of *Clostridium*	
Aerobic, photosynthetic	Species of *Rhodospirilhum*	
Cyanobacteria	Species of *Nostoc, Anabaena* and others	
II. Symbiotic Systems		
Host	Microorganisms	Location
1. Angiosperms		
Leguminous	Species of *Rhizobium*	Root Nodules
Non-leguminous		
Alnus, Casuarina	Species of actinomycetes	Root Nodules
Psychotria	*Klebsiella*	Leaf Nodules
2. Gymnosperms		
Certain Cycads	Certain unidentified species of bluegreen algae	Symbiotic relation not well documented
3. Ferns		
Azolla	*Anabaena*	Leaf pockets
4. Non-vascular plants		
Lichens	Fungi and blue-green algae	

Self Evaluation

One Mark

Choose the correct answer

1. The theory explaining passive absorption of mineral salts is:
   a.Ion exchange b.Carrier Concept
   c.Cytochrome pump theory d.None of the above.
2. Contact exchange theory was put forward by:
   a.Jenny and Overstreet b.Hylmo and Kramer
   c.Bennet and Clark d.De Vries and Curtis

Fill in the Blanks

1. The bacterium involved in symbiotic nitrogen fixation is.............
2. The nitrifying bacteria are ....and ....

Match

Bacillus ramosus	-	Yeast
Pseudomonas aeruginosa	-	Ammonification
Bennet & Clark	-	Denitrification
Rhodotorula	-	Carrier concept
Goldacre	-	Protein - lecithin carrier

Two Marks

1. Define Translocation of solutes/Ammonification/Denitrification/Donnan equilibrium.

Five Marks

1. Explain Munch's mass flow hypothesis.
2. Explain the theories of active transport of mineral salts.
3. Describe the transports of mineral by ion exchange.
4. Write notes on the cytochrome-pump hypothesis of mineral salt transport.
5. Describe the ringing experiment to demonstrate translocation of solutes.

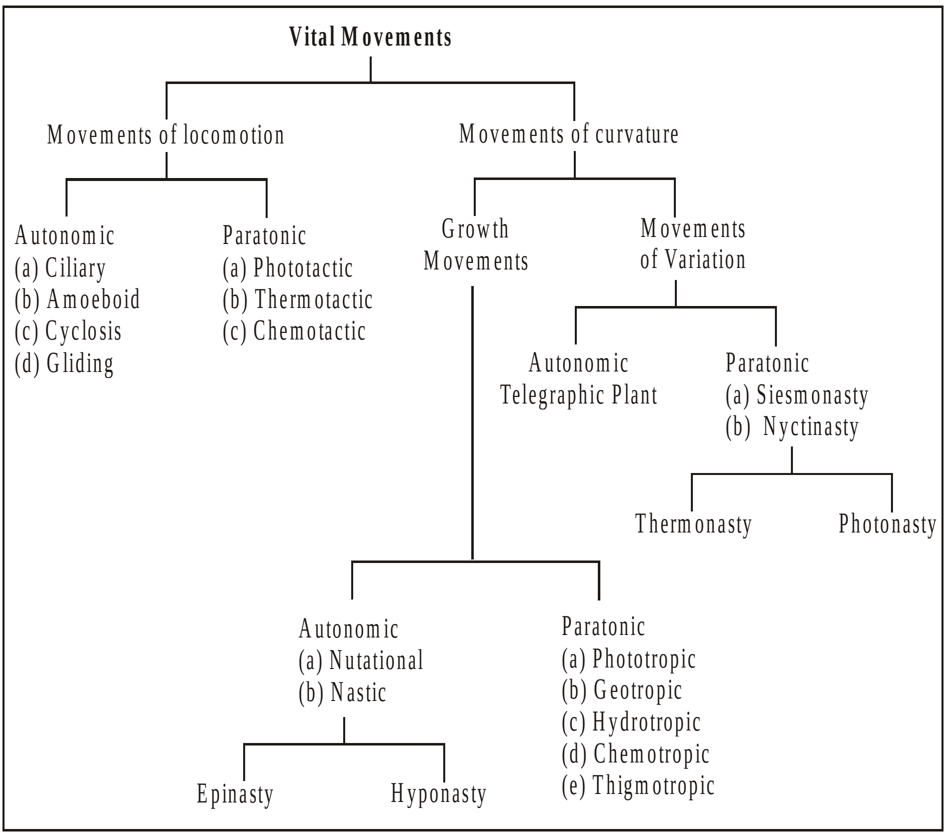
Ten Marks

1. Write an essay on the theories of mineral salt absorption.
2. Describe the Nitrogen cycle.
3. Explain biological Nitrogen fixation.

4. Plant Movements

Plants are sedantary living things generally lacking the power of locomotion. But they possess the property of irritability i.e. the ability to respond to an external or internal stimulus. This causes some kind of movement in plants, which is generally a very slow movement and often escapes notice by the human eye. But these movements can be actually demonstrated by a technique called **time - lapse motion picture** photography or by simply observing the plant at intervals of several hours and noting the changes in positions of the plant organs. The movements showed by plants can be classified broadly as (1) **Hygroscopic-** due to loss or gain of water and (2) **Vital-**due to irritability of the cytoplasm.

The vital movements may be further subdivided as follows.



I. Movements of Locomotion

These are generally very fast movements which may be (A) autonomic or Spontaneous and (B) induced or Paratonic. These movements are very common among lower plants and mostly exhibited by unicellular organisms. These movements are relatively faster and more pronounced.

(A) Autonomic Movements : The spontaneous locomotory movements may be

(i) Ciliary : due to beating of cilia as in *Paramecium.*

(ii) Amoeboid : by the formation of pseudopodia as in *Amoeba.*

(iii) Cyclosis : due to streaming of cytoplasm.

(iv) Gliding : as seen in *Hydra.*

(B) Paratonic movements

The induced locomotory movements are also called tactic movements induced by external stimuli. Based on the nature of stimuli, these may be of three types :

(i) Phototatic movement :

Seen in zoospores and gametes which are provided with a light sensitive eyespot which is attracted by low light intensities.

(ii) Thermotactic movement :

Movement in response to heat stimulus is seen in certain motile algae like *Chlamydomonas* which moves from a colder to a warmer place.

(iii) Chemotactic movement :

In bryophytes and pteridophytes, the swimming antherozoids are attracted towards the archegonium by chemical stimuli such as organic substances like sugar, malic acid and so on.

(iii) Movements of curvature

These movements are generally exhibited by higher plants which remain anchored in one place. These can change or move the position of their organs by means of curvature. These types of movements may be further classified as (A) Movements of growth and (B) Movements of Variation.

(A) Movements of growth :

There is a change in the position of the organ either due to increase in number of cells or enlargement of cells or both. These movements can be Spontaneous or Autonomic and Induced or Paratonic.

(ii) Spontaneous growth movements :

These include the (1) Nastic and the (2) Nutational movements

(1) Nastic Movements

These movements are generally observed in leaves, flowers, petals and bud scales. In these structures at some stage of development, growth in one surface is more than the growth on the other surface. There may be two types of such movements :

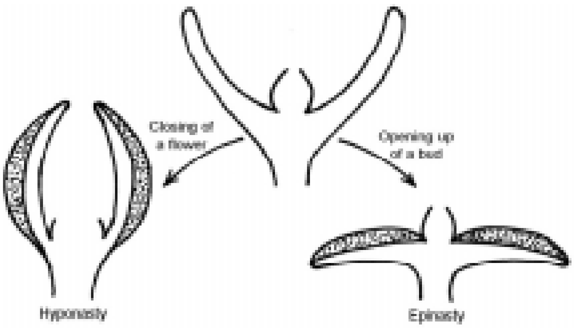


Fig.5.17 Nastic movements

Epinasty : If the upper or inner surface has more growth, the movement is called **epinasty**. An example for epinasty is the opening up of a flower and the drooping of a bud.

Hyponasty : This indicates rapid growth on the abaxial or lower side of an organ. An example for this is the unfolding of a fern frond and closing of a flower.

(2) Nutational Movement

This is an irregular movement shown by growing tips as they elongate. In tendrils and runners, there is a spiral type of growth of the stem apex called **circum nutation**. Ordinarily, nutational movements occur due to alternate change in the opposite sides of the apex. These movements are very slow and cannot be clearly seen.

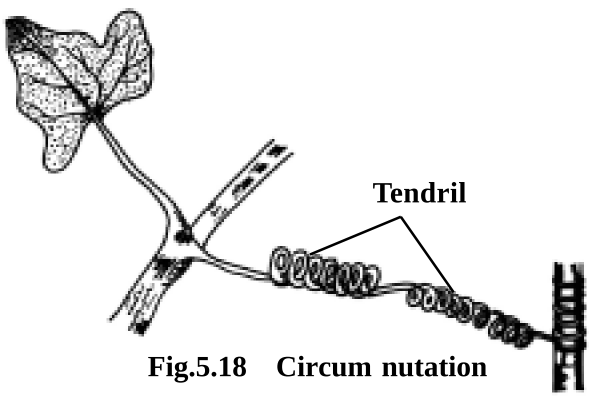


Fig.5.18 Circum nutation

(ii) Paratonic growth movements

These are the induced movements of growth caused by external stimuli such as gravity, light, water or contact. The movements show a directional relation to

the stimulus. The stimuli are effective in causing growth movements only when they are unidirectional. Such movements are generally known as tropic movements and the phenomenon is referred to as **tropism**. Based on the nature of stimulus, tropisms may be of various types.

(A) Geotropism
(B) Phototropism
(C) Hydrotropism
(D) Chemotropism
(E) Thigmotropism

4.1 Geotropism

This is also called **gravitropism** and it is the ability of a plant organ to assume a definite position in relation to the force of gravity. Plants show five different types of geotropic responses.

(i) Positive Geotropism

This is observed in primary roots where the taproot grows downwards, along the force of gravity.

(ii) Negative Geotropism

This is exhibited by the sporangiophores of fungi, shoots of mosses, pneumatophore of mangrove plants and the stems of flowering plants all of which grow upward against the force of gravity.

(iii) Diageotropism

Shown by rhizomes and runners which grow at right angles to the force of gravity.

(iv) Plagiogeotropism

This is the property of secondary lateral roots which grow obliquely downwards.

(v) Apogeotropism

The lateral roots and branches of higher plants are not sensitive to the stimulus of gravity.

Experiment to demonstrate negative geotropism in aerial stems

The effect of gravity on the plant can be demonstrated using an apparatus called **klinostat.**

Klinostat: The klinostat has a rotating pot like container mounted on an axial rod. A potted plant is fitted horizontally on the klinostat and is slowly rotated at about four rotations per hour. By this, the effect of gravity is completely eliminated, as all the sides of the plant are equally stimulated by gravity. If the rotation of the klinostat is stopped for a considerable period of time, then the tip of

the stem is observed to curve and grow upwards. This proves that the stem tip is negatively geotropic.

4.2 Phototropism

The tropic movement taking place as a response to the light stimulus is called **Phototropism**. Some of the plant parts such as stems, branches, leaves and, pedicels of flowers move towards the stimulus of light and are said to be **positively phototropic** while others such as roots and rhizoids which move away from the stimulus of light are said to be **negatively phototropic**.

Phototropism was first studied by **Charles Darwin** in 1880 in Canary Grass and oatcoleoptiles. Later on **F.W. Went** in 1923, suggested the involvement of auxins in this phenomenon.

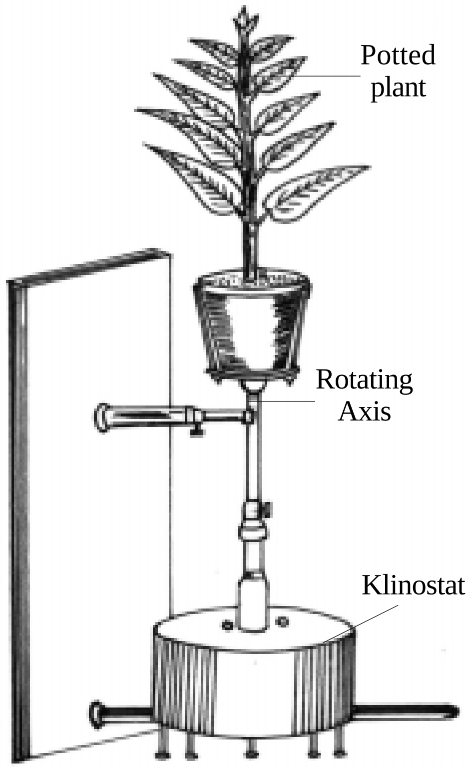


Fig. 5.19 Klinostat used to eliminate effect of gravity

Experiment to demonstrate positive phototropism in shoot tips

A darkened black box is taken having a small window at one side. A well-watered potted plant is placed inside the box. The is referred to as a **phototropic chamber** or **heliotropic chamber.**

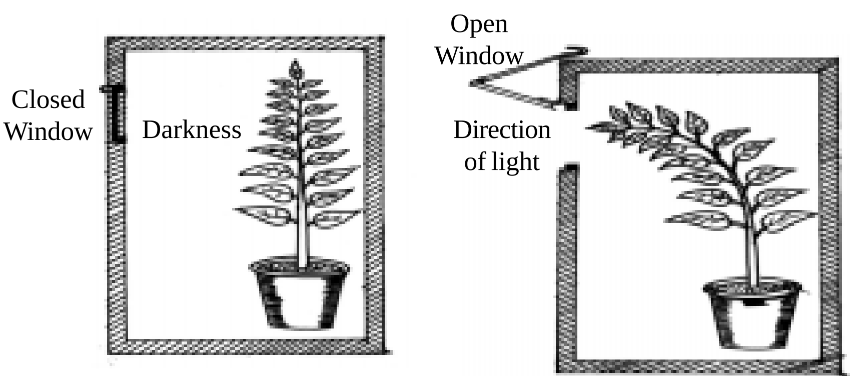


Fig. 5.20 Experiment to demonstrate phototropism

The window is kept closed for about 24 hours and the plant shows normal growth. If the window is kept opened, it is found after two days, that the shoot tip bends and grows towards light proving that it is positively phototropic.

4.3 Turgor Growth Movements

These types of movements are brought about by changes in turgor pressure of the cells causing the movement. These may be divided into two types.

(i) Autonomous or spontaneous and

(ii) Paratonic or Induced.

(i) Autonomous Turgor Movements

These do not require any stimulus and are observed in the **Indian Telegraphic plant - *Desmodium gyrans*.** Here the compound leaf shows three leaflets, one terminal large leaflet and two very small lateral, opposite leaflets.

The two lateral leaflets show rhythmic movements during the day. These move up, then move back, and then move down finally back to the original position. This type of movement is due to variation or change in the turgor pressure at the base of the stalk of each leaflet.

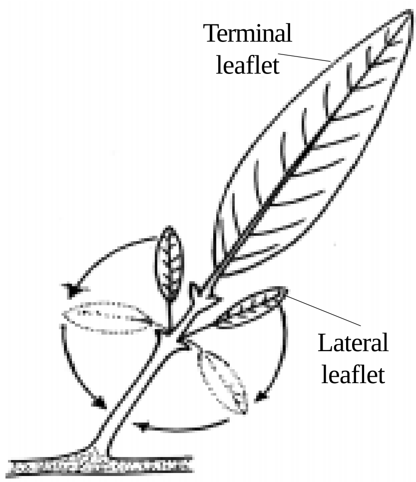


Fig. 5.21 *Desmodium gyrans* Indian Telegraphic plant

(ii) Paratonic or induced turgor movements

These are turgor movements induced by stimuli such as light, temperature and contact. These movements are also called Nastic movements and may be of various types such as

(i) Siesmonasty

(ii) Nyctinasty

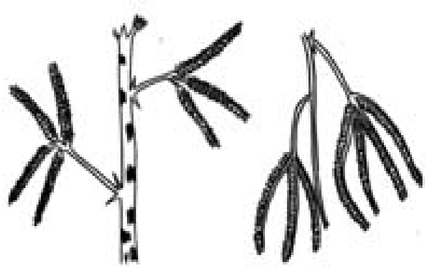


Fig.5.22 Siesmonasty - *Mimosa pudica*

(1) Siesmonasty

This means a response to shaking. The best example is ***Mimosa pudica*** (Touch - me - not plant) which is the sensitive plant. Such plants respond to stimuli such as touch, blow or mechanical shock by folding their leaflets and lowering

their leaves. This effect is caused by a change in the turgidity of the leaflets brought about by the movement of water into and out of the parenchymatous cells of the **pulvinus** or swollen leaf base.

(2) Nyctinasty or sleep movements

The movements are also called **sleep movements** and are caused by relative changes in cell size on the opposite sides of the leaf base called **pulvinus**. The movements are attributed to the amount of auxin, K^+ ions and therefore the movement of water. Entry of water to the lower side of the pulvinus causes the leaves to stand erect and the exit of water causes them to droop.

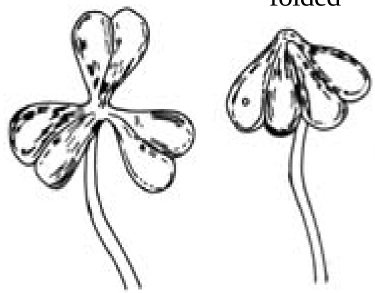


Fig.5.23 Photonasty - *Oxalis*

The nyctinastic movements may be of two types.

(A) Photonasty

The nastic movement caused in response to light is called **photonasty** or photonastic movement. The opening of leaves and flowers during day time and their closure at night is an example. The leaves of *Oxalis* show such a type of sleeping movement.

(B) Thermonasty

The nastic movement taking place in response to temperature is called Thermonasty or thermonastic movement. In *Crocus*, the flowers open at high temperature and close at low temperature.

Differences between tropic and nastic movements.

Tropic Movements	Nastic Movements
(1) The movements occur due to a unidirectional stimulus	These movements occur due to a diffuse stimlus
(2) The stimlus acts on protoplasm from one direction only	The stimlus acts on the protoplasm on all sides
(3) The response is directly related to the direction of the stimulus	The response has no relation with the direction of the stimulus but with the organ
(4) These are movements of curvature caused by unilateral growth	These are also movements of curvature but they are caused by reversible turgor changes.

SELF EVALUTION

One mark

Choose the right answer

1. Hygroscopic movements are related to
   (a) Loss of water (b) Gain of water (c) Both (d) None of the above
2. This is an autonomic movement of locomotion
   (a) Phototactic (b) Phototropic (c) Photonastic (d) Ciliary
3. Epinasty is a movement of
   (a) Curvature (b) Locomotion (c) Growth (d) None of the above
4. Reversible turgor changes are common in
   (a) Nutational movements (b) Tropism
   (c) Tactic movements (d) Nastic movements
5. Negative geotropism is not exhibited by
   (a) Roots (b) Stems
   (c) Sporangiophores of fungi (d) Pneumatophores of mangroves

Fill in the blanks

1. Siesmonasty is exhibited by the .... plant.
2. *Desmodium gyrans* shows .... movement.
3. Geogropism in shoots can be demonstrated using a ....
4. Rhizomes which run at right angles to force of gravity show ....

Two Marks

Define

Epinasty / Circumnutation / Photonasty / Thermonasty / Plagiogeotropism

Five marks

1. Describe autonomous movements of locomotion.
2. What are the paratonic locomotory movements.
3. Explain the spontaneous growth movements.
4. Give an account of geotropism in aerial shoots.
5. Describe an experiment to demonstrate phototropism.
6. Differentiate between tropic and nastic movements.

Ten marks

1. Write an essay on movements of locomotion.
2. Describe the turgor movements in detail.

VI. REPRODUCTION BIOLOGY

1. Reproduction in Angiosperms

1.a. Vegetative Propagation

Generally Angiosperms propagate by producing seeds, which is the result of sexual reproduction. However they resort to other methods of reproduction, such as vegetative propagation.

Plants belonging to this category propagate by a part of their body other than the seed. The structural unit that is employed in place of seed is called propagule.

Lower plants reproduce vegetatively through budding, fission, fragmentation, gemmae, resting buds, spores etc.

Methods of vegetative propagation have been further divided into two types.

A) Natural vegetative propagation and

B) Artificial vegetative propagation

A. Natural Methods of Vegetative Propagation

Vegetative Propagation by Roots

Some modified tuberous roots can be propagated vegetatively, when planted in soil. The buds present on the roots grow as leafy shoots called slips above ground and adventitious roots at their bases. Each slip gives rise to a new plant. eg. Sweet potato, Topioca, yam, Dahlia and Tinospora.

Adventitious buds develop on the ordinary roots of Dalbergia sisoo, Populus, Guava, Murraya sp, etc. which grow to form new plants.

Vegetative Propagation by Stem

In many plants, stem is modified to perform different functions. The modified stems perform three distinct functions (a) perennation, (b) vegetative propagation and (c) storage of food.

Modified stems which help in propagation can be classified into following three categories:

1. Underground
2. Subaerial
3. Aerial.

Propagation by Underground Stem

These plants develop non-green, under ground perennial stems. These store reserve food, propagate vegetatively and are adapted for perennation. They give rise to aerial shoots that grow actively during favourable conditions. On the approach of unfavourable conditions, the aerial shoots die. The underground stems remain dormant during the unfavourable conditions. Once the conditions become favourable, they produce new aerial shoots.

The various types of underground stems are

1. Rhizome, 2. Tuber, 3. Bulb, 4. Corm

Bulb

The stem is shortest and somewhat disc-like and does not contain any food material. Stem is covered by numerous thickened, overlapping leaves or leaf bases (usually called scales). The whole structure takes the form of a bulb. The short and reduced stem bears numberous adventitious roots at its base:

- **(a) Tunicated bulbs**: In this case, the fleshy scales completely surround the reduced stem forming the concentric layers around stem forming the concentric layers around one another. On the outside they are covered by a few dry scales forming a membranous covering, called the tunic. The fleshy scales are bases of the foliage leaves, eg., **Onion, etc.**

- **(b) Scaly bulbs**: Here, the leaves are small and scale-like and only overlap at the margins. There is also no outer tunic. The scaly bulbs are found in lilies, garlic, etc.

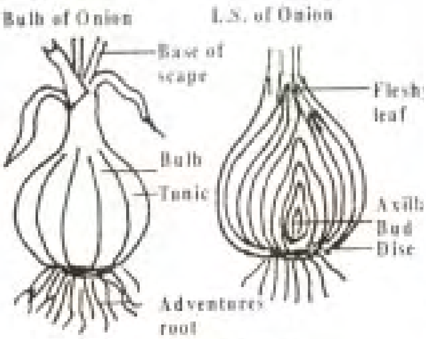


Fig : 6.1. Bulb

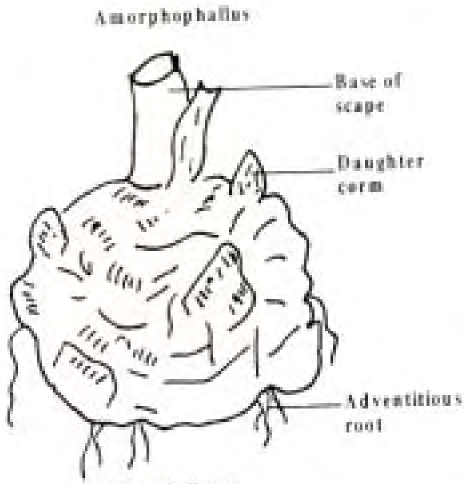


Fig : 6.2. Corm

In both the above types, axillary buds frequently develop in the axil of the fleshy scales. These develop into new bulbs or on separation from the parent bulb develop into new plants. They serve both for food storage and vegetative propagation.

Corm

It is more or less a condensed form of rhizome. It is a short, stout, solid and fleshy underground stem growing in the vertical direction. It is more or less rounded in shape or often somewhat flattened from top to bottom. It contains excessive deposits of food material and grows to a considerable size. It bears one or more buds in the axil of scale leaves and some of these buds grow up into aerial flowering shoots and from the base adventitous roots pass into the soil. Food materials get stored in the basal portion and in this way a new corm is formed. eg. Colocasia, Amorphophalus etc.

Propagation by Modified Subaerial Stem

These modifications are found in many herbaceous plants with a thin, delicate and weak stem. In such plants a part of the stem lives under-ground whereas remaining part of the stem is aerial. These plants bear adventitious roots and aerial branches at nodes. Such plants propagate quickly with the help of fragments of special branches. Subaerial modified stems are of the following types:

1. Stolon, 2. Offset.

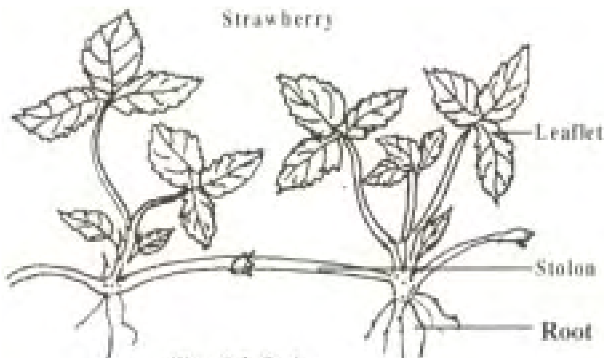


Fig : 6.3. Stolon

Stolons

These develop from underground stems. They grow horizontally outwards and bear nodes and internodes. They resemble the runners except that they are produced just below the surface of the soil, eg., Strawberry, Vallisneria etc.

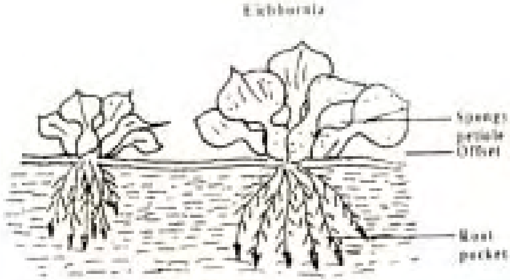


Fig : 6.4. Offset

Offset

These are also known as condensed runners. These originate as short, more or less thickened,

horizontal branches in the axil of lower leaves of the main shoots. Unlike a runner, an offset produces a tuft of leaves above and a cluster of roots below. On breaking off from the parent plant, each branch forms an independent plant. eg., *Pistia, Eichhornia* etc.

Propagation by Leaves

Leaves are not a common means of vegetative propagation in nature. However, *Bryophyllum* is known for its remarkable ability to reproduce by leaves. In *Bryophyllum* plantlets develop from the buds present on the marginal notches of the intact leaves. These plantlets become detached and develop into independent plants.

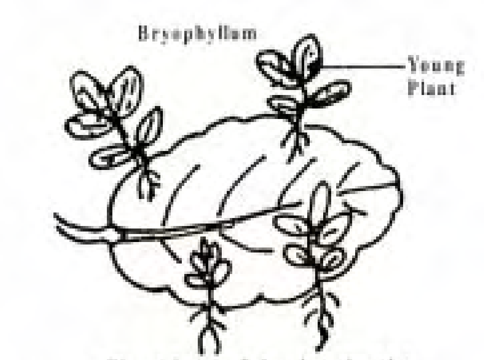


Fig : 6.5. A leaf showing plant lets

Propagation Through Bulbils

These are spherical multicellular, fleshy buds produced in the axil of foliage leaves in the place of axillary buds. They grow to form new plants, when shed and fall on the ground. eg. *Dioscorea, Oxalis, Pine apple*, etc.

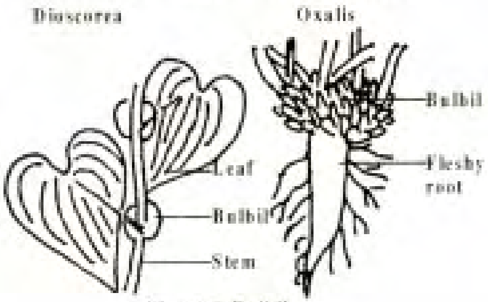


Fig : 6.6. Bulbils

Propagation by Turions

These are special type of fleshy buds that develop in aquatic plants. Eg. *Potamogeton, Utricularia*, etc. for vegetative propagation.

Horticultural importance of Natural vegetative propagation

Agriculturists and horticulturists use various means of natural vegetative propagation explained above for raising crops and garden plants for commercial purposes.

The chief advantage of vegetative propagation is the perpetuation of the desirable features of a selected plant. We are familiar with the fact that potatoes are propagated by whole tubers or their pieces, *ginger* and *banana* by the division of rhizomes, *Colocasia* and *Crocus* by the pieces of *corms, onion* and *garlic by bulbs, mint* and *chrysanthemum* by suckers and sweet potatoes by the pieces of tuberous roots.

B. Artificial Method of Vegetative Propagation

In addition to the natural methods of vegetative propagation as described above, several artificial methods of vegetative propagation are practised. Following are the important artificial methods of vegetative propagation.

Cuttings

The portion of any plant organ such as stem, root or leaf, used for vegetative propagation is called cutting. Stem cuttings are most commonly used for this purpose. Factors such as the optimum length and diameter of the cutting, age of the parent plant and season are to be considered, while selecting a cutting for each species.

Some of the plants propagated by stem cuttings are sugarcane, rose, *Bongainvillaea, Moringa, Hibiscus, Thepesia* etc.

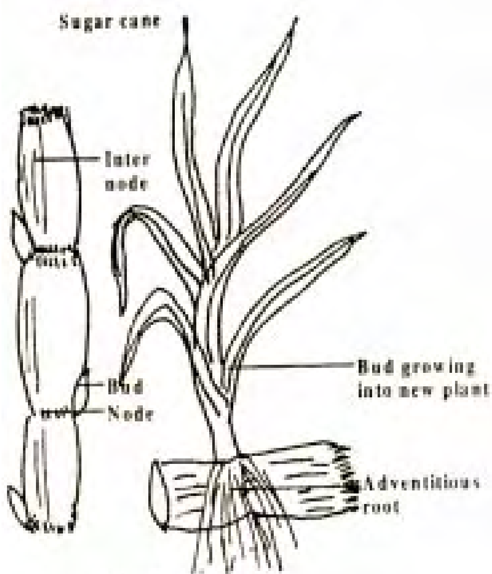


Fig : 6.7. Cutting

Grafting

It is the most common method of vegetative propagation. In this method part of two plants are joined in such as way that they grow as one plant. Grafting is done between the two closely related dicotyledonous plants having vascular cambia. The rooted supporting portion of one plant, called stock is joined with a twig of another plant called scion.

Advantages of Vegetative propagation

Vegetative propagation has a number of advantages. Some of these are as follows:

1. Vegetative propagation is a more rapid, easier and a less expensive method of multiplying plants which have either poor viability or prolonged seed dormancy.
2. It also helps us to introduce plants in new areas where seed germination fails to produce plants due to change in the soil and environmental conditions.
3. Plants like Bermuda grass or doob grass (Cynodon dactylon), which produce only a small quantity of seeds are mostly propagated vegetatively.

4. Vegetative propagation is the only known method of multiplication in plants like *banana*, seedless *grapes* and *oranges*, *rose* and *jasmine* that have lost their capacity to produce seeds through sexual reproduction.
5. Grafting permits the physical and physiological joining of separate individuals for the best economic advantage i.e. good qualities of two varieties can be combined in one composite plant.
6. The good qualities of a race or variety can be preserved indefinitely.
7. The greatest advantage of vegetative propagation is that all plants produced will have the same characters and hereditary potential as the parent plants. It is not possible in the plants raised from seeds, since it contains blended characters of both the parents.

SELF EVALUATION

One Mark

Choose the correct answer

1. In Hibiscus vegetative reproduction takes place by
   a. Stem b. Bud c. Rhizome d. Leaf.
2. The plant which propagate with the help of its leaves is
   a. Onion b. Cactus c. Potato d. Bryophyllum

Fill in the blanks

1. During grafting the part that becomes the supporting portion is called as ....
2. A piece of potato tuber can form a new plant if it has ....

Two Marks

1. What is grafting?
2. What is a bulbil?
3. Differentiate between stolon and sucker.
4. Why is grafting not possible in monocot plants?

Five Marks

1. Discuss the significance of vegetative propagation
2. What is vegetative propagation?

Ten Marks

1. Give a brief account of vegetative propagation
2. Describe different means of natural vegetative propagation.

1.b. Micropropagation

Micro propagation is a rapid method of vegetative multiplication of valuable plant material for agriculture, horticulture and forestry. In this process, a large number of plantlets are produced from a small mass of explanted plant tissue by the tissue and cell culture technique. The ability of every living plant cell to produce the entire plant is called totipotency. This is being exploited industrially to multiply plants which are difficult to propagate by conventional means.

Procedure for micropropagation

In this method, a small segment of explant is cultured in a nutrient medium; the explant may be a meristametic tissue of a stem tip, an inflorescence etc. The explant tissue produces callus during the period of incubation. After the production of enough amount of callus tissue, the callus is sub-cultured in a fresh M.S. Medium containing growth hormones auxin and cytokinin.

The sufficiently developed calluses are then transferred to regeneration medium where the calluses are induced to produce roots and shoots. After the proper development of roots and shoots, the individual planets are transferred to pots in a green house for further existence.

Sometimes the callus tissue can be homogenised and the homogenate is directly plated on the medium. The cell masses of the homogenate grow and produce new plantlets.

1. Multiple Shootlet Production

This process is adapted to produce multiple copies of a desirable plant by making use of shoot tips. The desirable plant is multiplied for being a rare hybrid or a sterile plant with unusual features or for obtaining individual plants of only one sex. In this process multiple buds are formed from the cultured shoot tips without intervention of a callus in response to specific treatments. These buds are grown into shoots and are subsequently induced to produce roots with the rooting hormones. The shoots are then planted in the soil to develop into new plants. The chief advantage of this technique is the large scale cloning of plants throughout the year in a very small space. More examples of micropropagation on a commercial scale have been reported in ***Potato, Bananas, Begonias, Chrysanthemums***, etc.

2. Somatic Embryogenesis

Somatic cells are cultured in electric shakers to obtain single cell suspensions. After sometime when the number of cells has increased to a maximum depending upon the amount of the nutrient medium, the culture is made stationary. Each cell starts differentiating into an embryo and proceeds through globular heart-shaped and torpedo shaped stages resembling the development of sexually produced embryos. Since these embryos develop from the somatic calls, they are called as **embryoids**. Thousands of somatic embryos (embryoids) can be produced in a small volume of the nutrient medium contained in a culture tube. Each of these embryoids can form a complete plant with a normal tap root system. Success has been achieved in ***Carrot, Celery*** and ***Alfalfa***

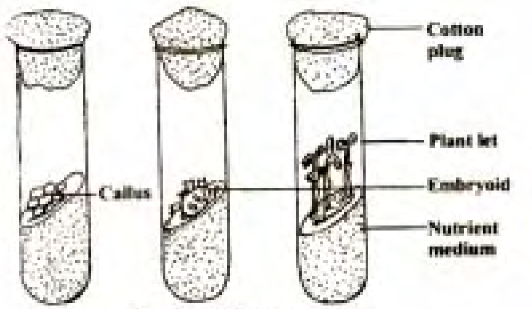


Fig : 6.8. Micropropagation

Micropropagation can be practiced in plants for many reasons

1. In some plants, seed production may be difficult or impossible. In such cases micro propagation is an effective technique for producing a large number of identical clones.
2. In some plants, normal sexual reproduction can take place, but only a small number of hybrids show the desired characters. The individuals resulting from micropropagation are all identical; they show a number of desired characters.
3. Sometimes a plant of desirable genotype may be required for planting. In plants like oil palms, identical clones are produced through micropropagation.
4. It is a standard multiplication method by which all the individuals produced are protected against mutation.
5. Till 1986, more than sixty species of forest trees were bred by using micro propagation.

SELF EVALUATION

Two Marks

1. Define totipotency.
2. What is Micropropagation?

Ten Marks

1. Write an essay on Micropropagation.

2. Sexual Reproduction

2.a. Pollination

The process of transfer and deposition of pollen grains from the another to the stigmatic surface of the flower is called pollination. It is an essential event in the sexual reproduction of seed bearing plants. Pollination is a pre-requisite for ensuring seed set and perpetuation of a species. Pollination is direct in Gymnosperms and indirect in Angiosperms.

There are two main types of pollination - self pollination and cross pollination.

I. Self Pollination

It is the process of transfer of pollen grains from the another to the stigma of either the same flower or another flower borne on the same plant. Accordingly, self pollination is of two types: autogamy and geitonogamy.

(A) Autogamy: (Gk. Auto = self, gamos = marriage):

It is a kind of pollination in which the pollen from the anthers of a flower are transferred to the stigma of the same flower. It occurs by three methods.

(i) Cleistogamy: (Gk. Kleisto = closed. Gamos = marriage):

Some plants never open to ensure complete self-pollination. This condition is called cleistogamy, eg. ***Commelina bengalensis***, ***Oxalis***, ***Viola***, etc. The cleistogamous flowers are bisexual small, inconspicuous, colourless and do not secrete nectar.

(ii) Homogamy

Anthers and stigma of the bisexual flowers of some plants mature at the same time. They are brought close to each other by growth, bending or folding to ensure self pollination. This condition is called homogamy, eg., ***Mirabilis (Four O. clock), Catharanthus (Vinca), Potato, Sunflower***, etc.

(iii) Bud Pollination

Anthers and stigma of the bisexual flowers of some plants mature before the opening of the buds to ensure self-pollination, eg., ***Wheat, Rice, Pea***, etc.

(B) Geitonogamy (Gk, geiton = neighbour, gamos = marriage).

It is a kind of pollination in which the pollen grains from the anthers of one flower are transferred to the stigma of another flower borne on the same plant. It usually occurs in plants which show monoecious condition (unisexual, male and female flowers are borne on the same plant).

Advantages of self-pollination

1. Chances of pollination are more.
2. Self-pollination maintains purity of the race and avoids mixing.
3. It need not produce a large number of pollen grains.
4. Flower need not possess devices such as large and showy petals, presence of scent and nectar, etc. to attract pollinators.

Disadvantages of self-pollination

1. Progeny continuously gets weaker after every generation.
2. Less chances of the production of new species and varieties.

II. Cross Pollination (Xenogamy, Allogamy)

Cross Pollination involves the transfer of pollen grains from the flower of one plant to the stigama of the flower of another plant. It is also called Xenogamy.

POLLINATION

- Self Pollination
  - Autogamy (Same flower)
  - Geitonogamy (Different flowers of the same plant)
- Cross Pollination (Xenogamy or Allogamy) Flowers from different plants of the same species
  - Abiotic agencies
    1. Anemophily (wind)
    2. Hydrophily (water)
  - Biotic agencies
    1. Entomophily (insects)
    2. Ornithophily (Birds)
    3. Chiropterophily (Bats)
    4. Malacophily (Snails)
    5. Myremecophily (Ants)

(Gk. Xenos = Strange, gamos = marriage) or allogamy (gk, allos = other, gamos = marriage. The main floral characteristics which facilitate cross pollination are

i) Herkogamy

Flowers are bisexual but the essential organs, the stamens and stigmas, are arranged in the flower, in such a way that self pollination becomes mechanically impossible. eg., ***Hibiscus sps; Gloriosa superba, etc.***

Hibiscus : The stigmas project far above the stamens.

Gloriosa superba : The style is reflexed away from the stamens.

ii) Dichogamy

Pollen and stigma of the flower mature at different times to avoid self-pollination. It is of two types.

a. Protography

Gynoecium matures earlier than androecium eg. ***Bajra, Aristolochia*** etc.

b. Protandry

Androecium matures and shed pollen gynoecium eg. **maize**.

iii) Self-incompatibility

In some plants, when the mature pollen fall on the receptive stigma of the same flower, it fails to bring about self pollination. It is called self incompatibility. Under such conditions, the cross pollination is the only option.

iv) Male sterility

The pollen grains of some plants are not functional. Such plants set seeds only after cross pollination.

v) Dioecism

Cross pollination always occurs when the plants are unisexual and dioecious. i.e. male and female flowers occur on separate plants. eg., ***Papaya***, some ***cucurbits*** etc.

vi) Heterostyly

The flowers of some plants have different lengths of stamens and styles so that self pollination is not possible eg. ***Primula, Linum***, etc.

Agents of pollination

Pollination is effected by many agents like wind, water, insects etc. On the basis of the agents that bring pollination, the mode of pollination is as follows :

1. Anemophily (Wind)
2. Hydrophily (Water)
3. Entomophily (Insects)
4. Ornithophily (Birds)
5. Chiropterophily (Bats)
6. Myrmecophily (Ants)

1. Anemophily (Wind pollination) (Gk, anemos = wind, philein = to love)

It is a mode of pollination or transfer of pollengrains from anther to stigma through the agency of wind. The flowers which are wind pollinated are called anemophilous. The anemophilous flowers are characterized by the following adaptations :

(i) Flowers are small colourless, inconspicuous, odourless and nectarless.

(ii) Calyx and corolla are either reduced or absent. Anthers are usually versatile.

(iii) When flowers are unisexual, male flowers are more abundant than female flowers. In bisexual flowers, the stamens are generally numerous.

(iv) Pollen grains are small, light, dry, dusty and sometimes winged (or saccate) so that they are easily blown away to long distances (upto 1300 km).

(v) Pollen grains of anemophilous flowers are produced in huge quantities. For example, a single flower of *Cannabis* produces, 5,00,000 pollengrains.

(vi) The flowers are well exposed in the air. In certain plants, they are produced above the foliage before the appearance of new leaves.

(vii) The stigmas are large, well-exposed, hairy, feathery or branched to catch the air-borne pollen grains.

(viii) In some plants, (eg., ***Urtica***), the anthers burst suddenly to throw the pollen grains into the air (gun-powder mechanism)

The common examples of wind pollinated flowers are - ***grasses, sugarcance, bamboo, coconut, palm, date palm, cannabis (bhang), maize*** etc. fig.

2. Hydrophily (Water Pollination) : (Gk, Hydro = water, Philein = to love)

Hydrophily occurs only in a few aquatic plants. Hydrophily is of two types, hypohydrophily and epihydrophily.

i) **Hypohydrophily** is true hydrophily which occurs below the surface of water. It occurs in totally submerged plants and their pollen grains are water borne. eg., ***Zostera marina, Ceratophyllum***, etc.

a. Ceratophyllum desnersum

In **Ceratophyllum** desnersum (a submerged fresh water plant), the male flower bears 30-45 stamens. The mature anthers break at the base, rise to the surface of water and dehisce there. The liberated pollen germinate and sink in water. While sinking, they come in contact with stigma of female flowers to effect pollination.

b. Zostera marina

In Zostera marina, the pollen grains are elongated (upto 2,500 mm), needle like and without exine. They have the same specific gravity as that of water, therefore float below the surface of water. When they reach the stigma, they oil around it and germinate.

3. Entomophily (insect Pollination)

The important pollinating insects are bees, butterflies, moths, wasps, bettles etc. The insects visit the flowers for nectar, edible pollen grains or shelter. Bees are the chief visitors of flowers and they obtain both nectar and pollen from the flowers. They have **pollen sacs** or **pollen baskets** for collecting pollen. The important characteristics of insect pollinated flowers are as under.

1. The flowers are large or if small they are grouped into inflorescence
2. The flowers are usually brightly coloured and have specific odour.
3. The flowers usually possess nectar or edible pollen.
4. They produce fewer pollen grains.
5. Anthers and stigmas are commonly inserted.
6. Stigmas are usually unbranched and may be flat or lobed.

A detailed study of the inter-relationship between the structure of flower and insect pollinators clearly indicates that some angiospermous plants are dependent upon a particular type of insect for pollination. Some classic examples are as follows :

a. Pollination in Salvia

The genus ***Salvia*** belongs to family Labiatae (Mint family) in which the gamopetalous corolla is two-lipped (bilabiate). The lower lip provides platform for the visiting insect and the upper lip is just like a hood which protects the floral organs. The flowers are protandrous. Each flower has two epipetalous stamens located in anterio-lateral position. Each stamen has a short filament and an elongated curved connective. The anther has two parts - one half is sterile and another half

is fertile. Both the parts of anther are separated apart due to elongation of connective. The elongated connective has two unequal arms. The upper arm is long and curved. It bears the fertile lobe of anther. The lower arm of connective is short and bears the sterile lobe of anther. The two sterile lobes jointly form a sterile plate of tissue which is placed at the mouth of corolla tube and partly blocks the path of the visiting insect. The upper fertile lobes are sheltered in the upper lip of corolla. As a bee visits the young flower and moves inward in search of nectar, its head pushes the sterile plate which brings down the fertile anther lobes to strike against its back. The pollengrains are deposited upon the back of the bee. When the pollen-dusted bee visits older flower (with protruded bilipped stigma), its back rubs against the mature stigma bringing about the pollination.

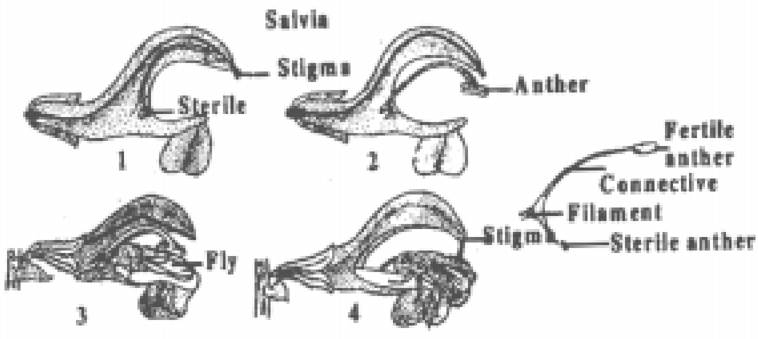


Fig : 6.10. Pollination by insect

Since the bisexual flowers of *Salvia* are protandrous, (anthers mature earlier than the gynoecium), cross pollination occurs only when pollen-dusted bee visits older flowers with mature gynoecium.

4. Ornithophily (Pollination by birds)

Ornithophily (Gk. Ornis = bird, philein = to love) is a mode of pollination performed by birds. The act of pollination is not performed by all the birds except a few. The most common bird pollinators are Sun bird, Humming bird, Crow, Bulbul, Parrot, Mynah, etc. The birds visit a large variety of flowers such as ***Bombax*** (Red Silk Cotton), ***Erythrina*** (Coral Tree), ***Callistemon*** (Bottle Brush), ***Bignonia, Agave, ete***. Over about 100 species of Australian plants are pollinated by birds. Humming bird pollinates while hovering over the flowers and sucking nectar. The bird can derive about half of its body weight of nectar in a single day. The nectar is chiefly made of sugars and provides a sweetdrink to the bird.

The ornithophilous flowers are characterized by the following adaptations:

i) The flowers are usually large in size. They have tubular or funnel-shaped corollas.

ii) The flowers are brightly coloured (such as red, yellow, orange, blue, etc.) which attract the birds from long distances.

iii) The flowers produce abundant watery nectar.

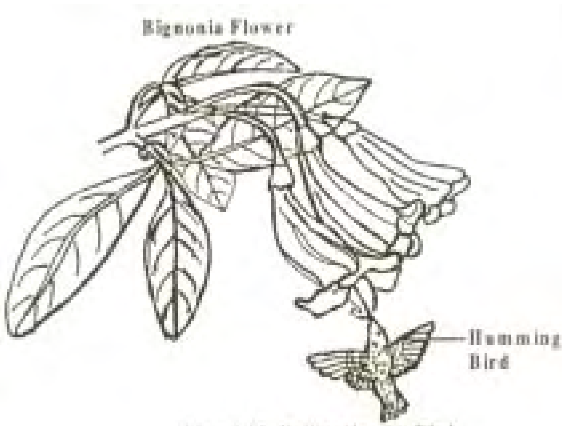


Fig : 6.13. Pollination by Bird

5. Chiropterophily (Bat Pollination)

It is a mode of pollination performed by bats. The bats are nocturnal flying mammals which move swiftly and transport pollen grains to long distances, sometimes over 30 kms. The flowers they visit are large, dull-coloured and have a strong scent. Chiropterophilous flowers produce abundant pollen grains and secrete more nectar than the ornithophilous flowers. Some of the common chiropterophilous plants are - ***Kigelia pinnata*** (Sausage Tree), ***Adansonia*** (Baobab Tree), ***Bauhinia megalandra, Anthocephalus*** (Kadam Tree), etc. Each flower of ***Adansonia*** (Baobab Tree) has 1500-2000 stamens.

6. Myrmecophily

Sometimes ants take their food or shelter on some trees such as ***Mango, Litchi, South American Acacia*** and so on. These ants act as body guards of the plants against any disturbing agent and also helps in pollination.

The pollination performed by any type of animal is called **Zoophily**.

Advantages of cross pollination

i) Cross pollination brings about genetic recombination and production of new varieties (variations).

ii) Cross pollination results in healthy and stronger offsprings due to phenomenon of hybrid vigour.

iii) Several crop plants (such as Mustard, Safflower, Sunflower, Clover, Cucurbits), give significantly higher yields if bees are available and cross pollination is allowed to occur.

iv) Variations caused due to cross pollination may result in production of disease resistant plants.

v) Cross pollination results in the production of seeds in self-sterile plants (i.e., Pollen grains fail to grow on the stigma of the same flower).

Disadvantages of cross pollination

i. Cross pollination is not economical. The plants waste a lot of energy and food materials in unnecessary adaptations and devices to bring about pollination.

ii. Cross pollination is uncertain because a factor of chance is always involved.

iii. It involves addition of some undesirable character or loss some important character.

SELF-EVALUATION

Choose the correct answer

1. Fragrant flowers with well developed nectaries are an adaptation for
   a. Zoophily b. Entomophily c. Anemophily d. Hydrophily
2. Hypohydrophily occurs in
   a. Vallisneria b. Ceratophyllum c. Hydrilla d. All the above

II. Fill in the balnks

1. Myrmecophily is a beneficial association between some flowering plants and
2. A bisexual flower which never opens in its life span is called
3. Pollination by bat is called

III. Two Marks

1. What do you mean by hydrophily?
2. Name different types of pollination.
3. Give the characteristics of insect pollinated flowers.
4. Name two plants which are
   a. Wind Pollinated b. Water Pollinated c. Insect Pollinated

Five Marks

1. Give the characters of wind pollinated flowers.
2. Write short note on: Pollination in *Calotropis*.
3. What is entomophily? Describe the features of entomophilous flowers.

Ten Marks

1. Give an account of different types of pollination found in Angiosperms.

2.b. Development of male and female gametophyte

The stamen or microsporophyll consists of a filament, anther and a connective. Each anther consists of two anther lobes connected by a midrib known as connective. Each anther lobe contains two pollen sacs or microsporangia.

Development of microsporangium

The cross section of a very young anther shows a mass of undifferentiated cells surrounded by epidermis. The rows of hypodermal cells called microsporangial initial or archesporium becomes differentiated in each lobe of the anther.

Each microsporangial initial divides by periclinal division to form outer primary parietal cell and inner primary sporogenous cell. The primary parietal cell repeatedly divides to form the wall layers as described below :

A. Epidermis

It is the outermost layer of a young anther and undergoes only anticlinal divisions.

B. Endothecium

Immediately below the epidermis, the cell layers are radially elongated and develop fibrous thickenings. These cells are hygroscopic in nature and help in dehiscence.

C. Middle layer

Usually one to three middle layers are found below the endothecium. They become crushed at the time of meiotic division in the pollen.

D. Tapetum

The cells of the innermost parietal layer possess dense protoplasm and the food entering into the sporogenous cells pass through it. Thus it serves as a nutritive layer for the developing microspore. The tapetum may be glandular or amoeboid based on the behaviour of the cells during sporogenesis.

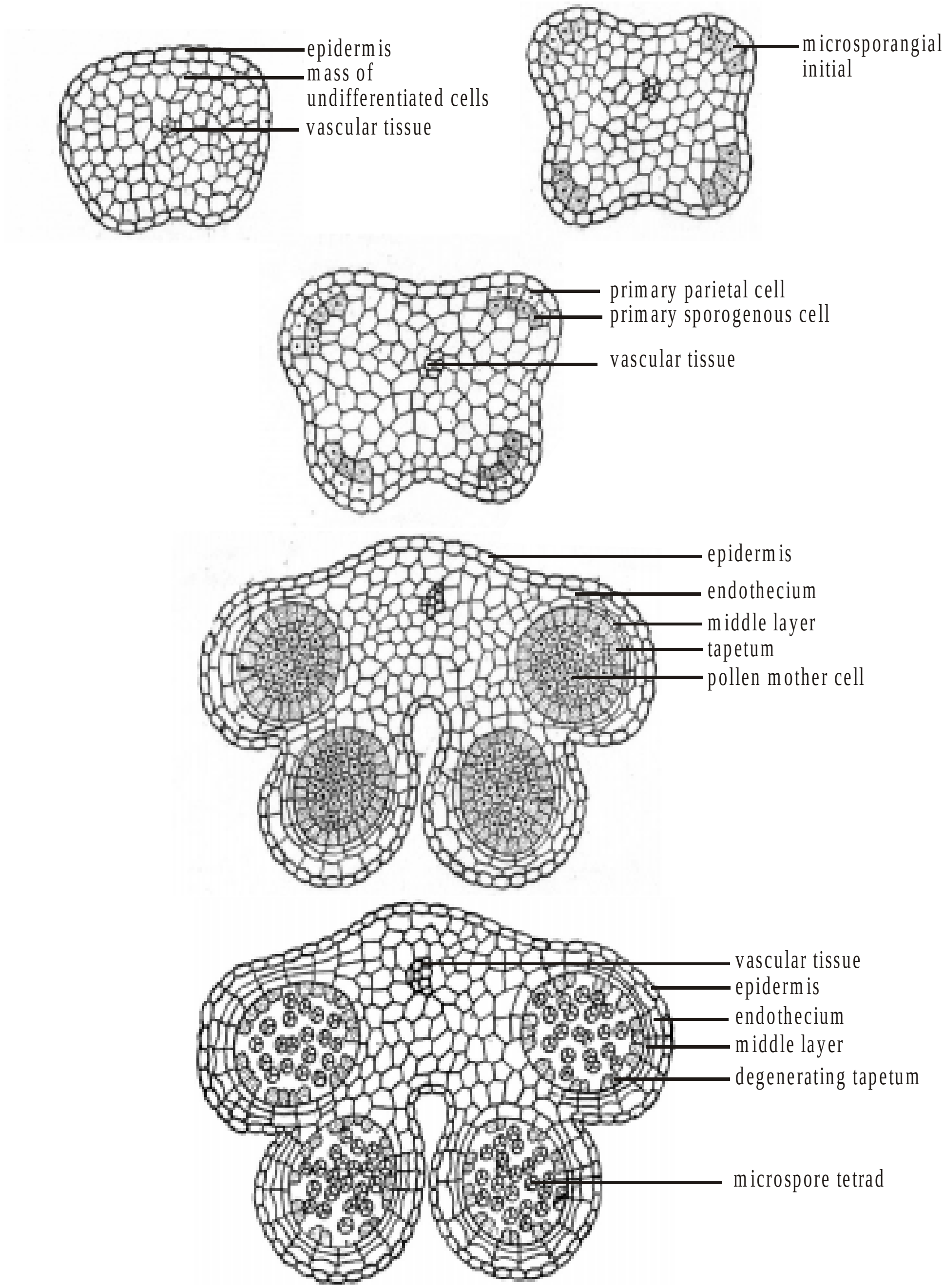


Fig. 6.14 Development of microsporangium

E. Sporogenous tissue

The primary sporogenous cells undergo several divisions to form microspore mother cells. Each microspore mother cell divides meiotically to produce four microspores or pollengrains which will have half the (n) number of chromosomes.

F. Microspore or pollengrain

Each pollengrain is unicellular and uninucleate having a two layered wall. The outer layer is called exine and the inner wall is called intine. The exine is provided with spinous outgrowth or different types of ornamentation. The intine is thin, delicate and made up of cellulose.

The exine is not laid uniformly over the intine. The places where exine is not laid is very thin. These thin points are known as germ pore.

Development of male gametophyte

The microspore is the first cell of the male gametophyte. It has a haploid nucleus. The microspore starts germinating while it is still within the microsporangium or pollen sac.

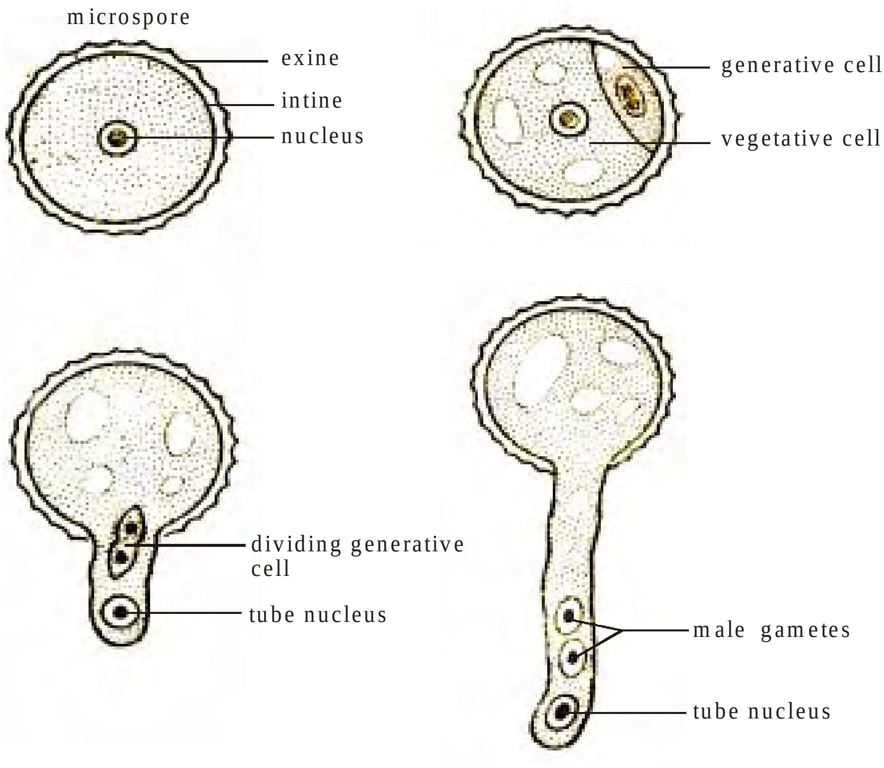


Fig.6.15 Development of male gametophyte

The nucleus of the microspore divides to form a generative nucleus and a tube nucleus or vegetative nucleus. The cell wall is formed resulting in two unequal cells called generative cell and vegetative cell. The generative cell is lenticular or spindle-shaped. Generally, the microspore is shed in the two-celled condition for pollination.

The two celled pollen grain on the stigma of a flower becomes three celled as a result of the division of the generative cell into two male cells or two male gametes. The pollen grain absorbs water and the intine grows out through a germpore to form a pollen tube, which discharges the two male gametes into the embryosac.

Development of female gametophyte

Megasporophyll

The carpels of angiosperm is known as megasporophyll. It is differentiated into three regions-ovary, style and stigma. The ovary contains ovules or megasporangium.

Megasporangium or ovule

An ovule or megasporangium may arise from the inner surface of the base of an ovary. Each ovule is attached to the placenta by a stalk called **funicle**. The point of attachment of the ovule to the funicle is known as **hilum.** The funicle continues beyond the hilum along the body of the ovule and forms a ridge called **raphe.**

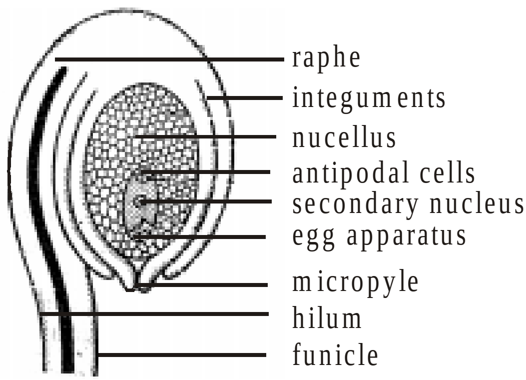


Fig.6.16 LS of a mature ovule

The body of the ovule consists of a parenchymatous mass of tissue called **nucellus**. The nucellus is surrounded by one or two coverings called integuments. The integuments do not completely cover the nucellus, but leaves a small opening at the tip called micropyle.

Megasporogenesis

Usually a single hypodermal initial known as primary archesporial cell is differentiated at the apex of the nucellus. The primary archesporial cell divides periclinally into outer primary parietal cell or primary wall cell and inner primary sporogenous cell.

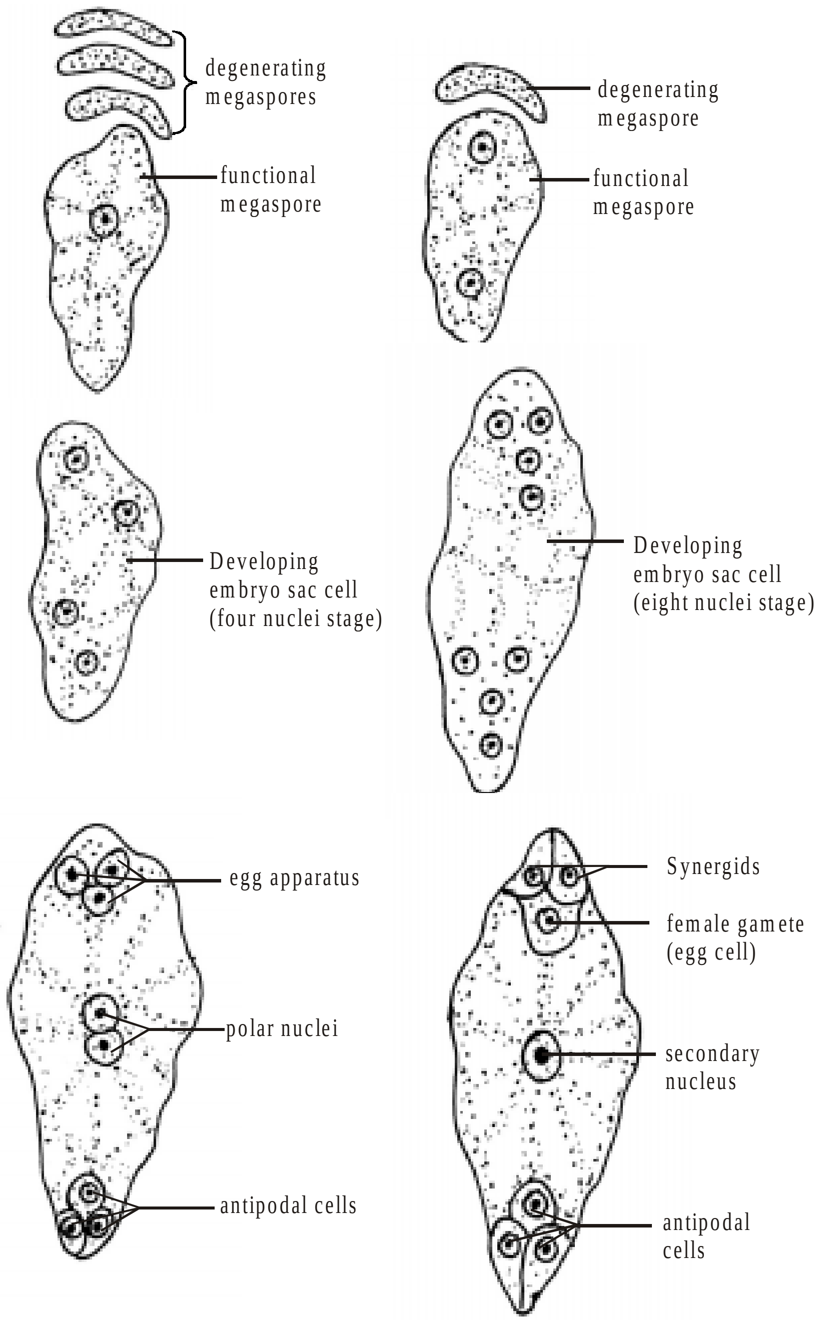


Fig.6.17 Development of female gametophyte

The primary parietal cell may or may not divide. The primary sporogenous cell directly behave as megaspore mother cell. The megaspore mother cell undergoes meiotic division to form four megaspores. The four megaspores thus formed are arranged in an axial row forming a linear tetrad. Usually only one megaspore of the tetrad is functional and grows at the expense of other three, which degenerate. The functional megaspore enlarges and forms the embryosac.

Embryosac

The embryosac has three protoplasts of the egg-apparatus towards the micropylar end. Of the three cells constituting the egg-apparatus, one is the **egg** cell (female gamete) and the other two are known as the **synergids.** The egg cell, which is enlarged lies below the synergids. At the chalazal end are three **antipodal** cells. These antipodal cells have no definite function and soon gets disorganized. In the centre of the embryosac is the **secondary nucleus.**

Types of ovule

There are six types of ovules.

1. Orthotropous or atropous ovule (ortho-straight, tropous - turn)

The body of the ovule is erect or straight. The hilum, chalaza and the micropyle lie in a straight line e.g. **Polygonum.**

2. Anatropous ovule (ana - backward or up, tropous - turn)

The body of the ovule becomes completely inverted during the development so that the micropyle lies very close to the hilum (eg) Gamopetalae members.

3. Hemi-anatropous or hemitropous ovule

The body of the ovule is placed transversely at right angles to the funicle. The micropyle and chalaza lie in one straight line e.g. ***Ranunculus*****.**

4. Campylotropous ovule (kampylos - curved)

The body of the ovule is curved or bent round so that the micropyle and chalaza do not lie in the same straight line. e.g. ***Leguminosae*****.**

5. Amphitropous ovule

The curvature of the ovule is very much pronounced and the embryosac also becomes curved e.g. ***Allismaceae,*** and ***Butomaceae*****.**

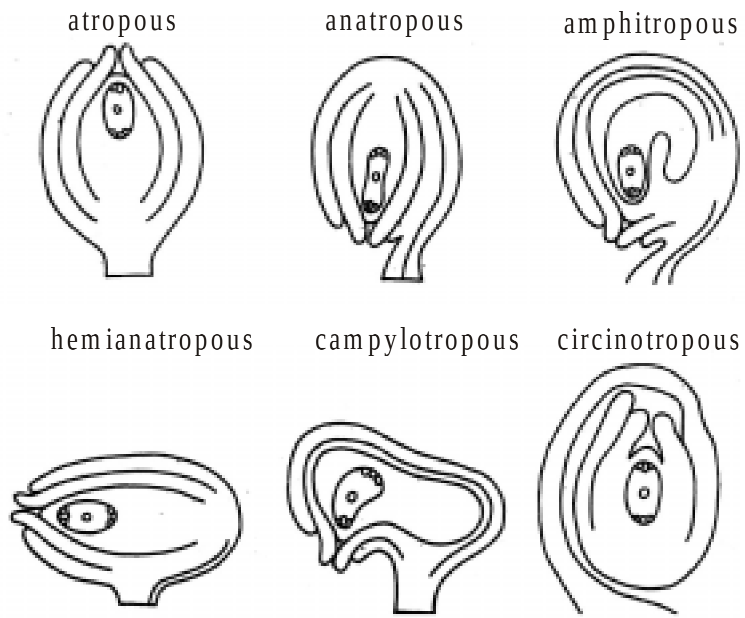


Fig.6.18 Types of ovules

6. Circinotropous ovule

The nucellus and the axis are in the same line in the beginning but due to rapid growth on one side, the ovule becomes anatropous. The curvature continues further and the micropyle again points upwards (e.g.) ***Opuntia.***

SELF EVALUATION
Two marks

Write notes an

1. Endothecium
2. Middle layer
3. Tapetum
4. Germpore
5. Megasporangium
6. Anatropous ovule
7. Circinotropous ovule

Five Marks

1. Explain the wall layers of a mature anther
2. Explain the structure of a mature pollen grain.
3. Give an account of megasporogenesis.
4. Explain the structure of a mature embryosac.

Ten Marks

1. Describe the development of microsporangium till the formation of microspores.
2. Give an account of the development of male gametophyte.
3. Trace the development of megasporangium upto the maturation of embryosac.
4. Explain the structure of mature ovule of angiosperms.
5. Explain the different types of ovules.

2.c. Double fertilization

The fusion of the male and female gametes is called fertilization. The process was first discovered by **Strasburger** (1884) in ***Monotropa***

Siphonogamy

In seed plants, the male gametes arebrought to the eff containing female gametophyte by a pollen tube, the phenomenon is called **siphonogamy.**

Type of pollen entry

The pollen tube enters the ovule either through the micropyle **(Porogamy** eg. Lily), Chalaza (**Chalazogamy** eg. **Cauarinas**) or the integuments (**Mesogamy-** eg. *cucurbita) and* and discharges the two male gametes or sperms into the embryo sac. The pollen tube bores through nucellus and finally penetrates the wall of the embryo sac. It passes between a synergid and the egg cell or penetrates between the two synergids. Later one or both of the synergids degenerate. Inside the embryo sac, the pollen tube ruptures and the two male gametes are set free near the egg apparatus.

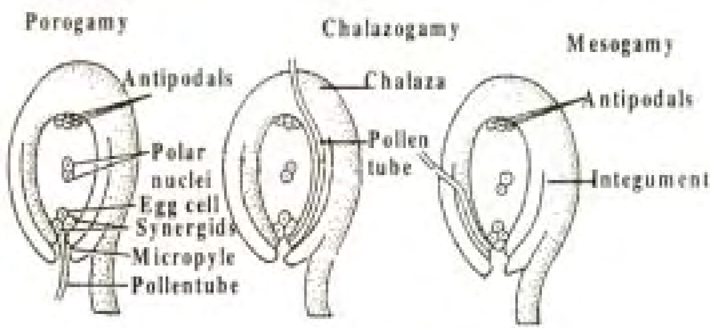


Fig.6.19. Entry of pollen tube into the ovule

Syngamy or true fertilization

Out of the two male gametes, one fuses with the egg nucleus and forms a diploid **zygote.** This process of gametic fusion is called **syngamy** or **true fertilization.** It is also known as **generative fertilization.**

Triple fusion

The second male gamete moves further the central cell and fuses with the two haploid polar nuclei or diploid secondary nucleus to form a triploid **primary endosperm nucleus.** This process involving the fusion of three necle is called **triple fusion.** It is also called **vegetative fertilization**. The central cell is now called **primary endosperm cell.**

The whole phenomenon of fertilization involving the fusion of one male gamete with the egg. together with the fusion of second male gamete with the

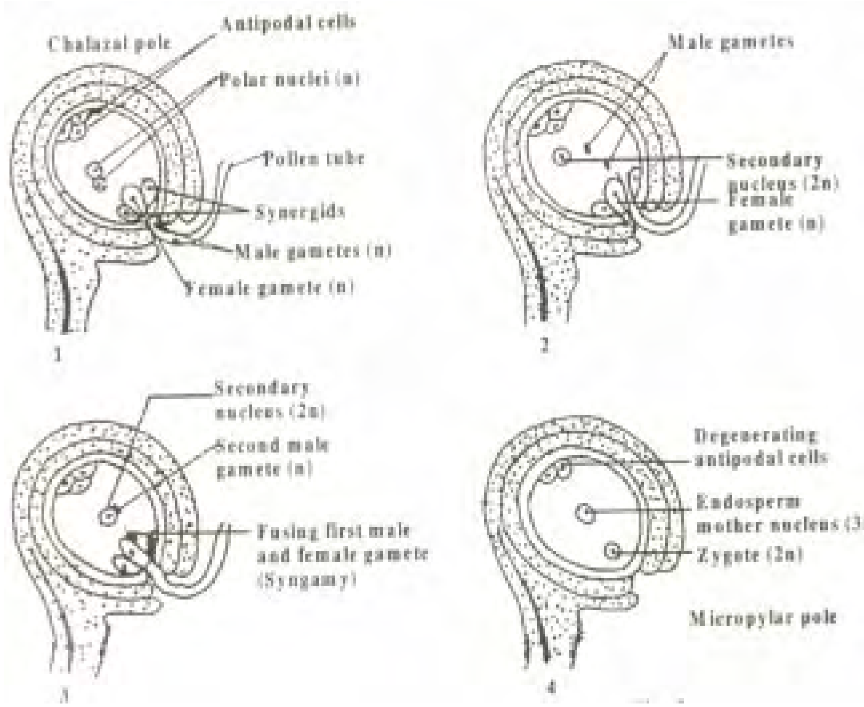


Fig.6.20 L.S. of ovule showing different stages of double fertilization

polar nuclei is called double fertilization. It involves both syngamy and triple fusion. Double fertilization is a unique feature of angiosperm and is necessary and is necessary for the production of viable seeds in the flowering plants. It was first observed by **Nawaschine(1898)** in **Fritillaria** and **Lillium.**

Significance of double fertilization

Double fertilization is found to be universal occurrence among angiosperms. It must occur within the ovule for the setting of viable seeds. Following are the significance of double fertilization.

1. In angiosperms the growth of the embryo sac (female gametophyte) stops at 8 nucleate or 7 celled stage. The fusion of second male gamete with the polar nuclei or secondary nucleus, provides stimulus to one of its cells to resume growth and form the nutritive tissue or endosperm.

2. Double fertilizationensures that the nutritive tissue or endosperm is formed only when the formation of embryo has been confirmed by fertilization of egg. If fertilization fails due to some reason, no endosperm will be formed. Thus no energy of the plant will be wasted on this account in angiosperms.

3. It provides characteristics tonutritive tissue called endosperm.

Post fertilization changes

After fertilization the sepals,petals, stamens, styles and stigma usually wither and fall off. The calyx may persis(e.g. tomato, brinjal) and even show growth (eg. **Physalis).** The zygote undergoes a number of mitotic divisions and forms a multicellular **embryo.**The primary endosperm nucleus also undergo mitotic division to form a food laden tissue called endosperm. The ovules mature into seeds and the ovary containing the ovules enlarges and forms the fruit.

Parts before fertilization	Parts after fertilization	
1. ovary	-fruit	
2. ovary wall	-pericarp	
3. ovule	-seed	
4. funicle	-stalk of the seed	
5. hilum	-hilum	
6. nucellus	-perisperm	
7. outer integument	-testa	Seed coat
8. inner integument	-tegmen	
9. micropyle	-micropyle	
10.Fertilized egg	-Emdosperm	
11.Synergids	-Degenerate	
12.Fertilized Secondary nucleus		
13.Antipodal cells	-Degenerate	

SELF-EVALUATION
One Mark
Choose the correct answer

1. The embryo sac in a typical dicot at the time of fertilization is
   a. 8 celled   b. 6 celled   c. 7 celled   d. 5 celled

2. Process of fusion between male and egg nuclei are
   a.Syngamy   b.Conjugation   c.Double fertilization   d. Triple fusion

Fll in the blanks

1 Double triple fusion. What is the product of this process?

2. What is double fertilization?

Ten Marks

1. Describe the process of endosperm and embryo formation in flowering plants.

2.d. Development of dicot embryo

The zygote divides transversely to form a two-celled proembryo. The cell towards the micropyle is known as the basal cell and the other is known as terminal cell.

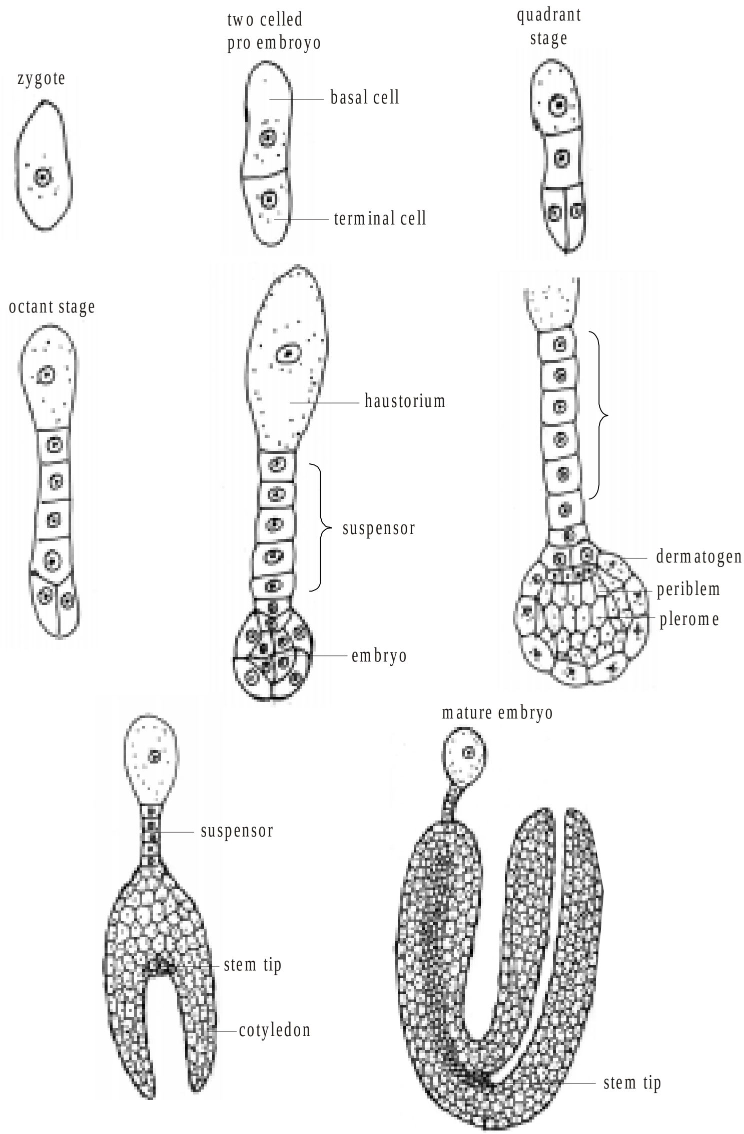


Fig.6.21 Dicot embryo development

The basal cell undergoes several transverse divisions to form a long **suspensor.** The terminal cell divides longitudinally twice to form four cells. This four-celled stage of terminal cell is called **quadrant stage.** The four cells of the quadrant stage now divide transversely to form an **octant stage** of eight cells arranged in two tiers of four cells. The lower tier gives rise to the stem tip and cotyledons, while the upper tier is meant for the formation of hypocotyl.

This is followed by periclinal division in the octant cells to give rise to eight outer cells, and eight inner cells. The eight outer cells form the **dermatogen,** which divide anticlinally and develop into the **epidermis.** The inner cells form the **periblem** and **plerome**. The cortex develops from the periblem and stele from the plerome. The basal cell divides several times to form a long suspensor of six to ten cells. The lowermost cell of the suspensor nearest to the developing embryo is known as **hypophysis.** The hypophysis, by repeated divisions, gives rise to root cap, epidermis and cortex of the root.

Further enlargement of hypocotyl and cotyledon result in a curvature of the cotyledons. The embryo at this stage appear as a horse-shoe shaped structure. In the mature embryo, the stem tip is terminal and the two cotyledons occupy the lateral position.

2.e. Parthenogenesis and parthenocarpy

Parthenogenesis

When the egg cell remains unfertilized and develops into a normal embryo, it is called parthenogenesis. Parthenogenesis is of two types.

(A) Haploid parthenogenesis

In haploid parthenogenesis, the haploid female gamete or even the haploid male gamete develops into an embryo.

(B) Diploid parthenogenesis

In many plants, the megaspore mother cell does not undergo meiotic division and forms diploid embryosac. As a result, the egg is always diploid. Such diploid and unfertilized egg divides parthenogenetically and produces normal diploid embryo. This embryo is devoid of a set of genes from the male parent. This type of parthenogenesis is known as diploid parthenogenesis.

Induced parthenogenesis

Parthenogenesis can be induced in the following ways :

(1) Exposing the mature flowers to high or very low temperature after pollination.

(2) Exposing the flowers to x-ray during meiosis.

(3) By injecting certain chemical substances into the ovaries.

Parthenocarpy

The phenomenon of producing seedless fruits without fertilization is known as parthenocarpy.

Induced parthenocarpy

Parthenocarpy can be induced in many ways. In some cases mutation or hybridization brings about parthenocarpy. Application of auxin and gibberellin, pollinating the stigmas with foreign pollengrains and treating the stigmas with the extract of the pollen are some other methods by which parthenocarpy can be induced. Indole butyric acid is the most suitable chemical to bring about parthenocarpic fruits of natural size.

Parthenocarpy is useful in producing seedless fruits and help in enrichment of nutrients.

SELF EVALUATION

Two Marks

Five Marks

1. What is parthenogenesis? How it can be induced?
2. Give an account of parthenocarpy

Ten Marks

1. Trace the development of dicot embryo

3. Germination of Seed

3.a. Parts of Seed

Seed is aripened ovule which contains the embryo or the miniature of plant body. Seeds of different plants vary in their size and shape. However, the general plan of structural organization of seed remains almost the same.

Part of a seed

Every seed an outer covering called seed coat. It develops from the integuments of the ovule. The outer coat is called **testa** and the inner layer is called tegmen. If only one covering is present in the seed, it is called testa. The testa is hard andleathery whereas **tegmen** is thin and membranous. Sometimes tegmen remains fused with the testa. The outer surface of seed shows a scar or mark of attachement with the seed stalk. It is called**hilum.**There is a small pore, called **micropyle,** which represents the micropyle of ovule. Some seeds also show the place of origin of seed coats (**chalaza**) and the part of funiculus fused with seed wall (**raphe**).

The seed coat encloses an embryo which is differentiated into **radicle, plumule** and **cotyledons**. The radicle, when elongated, gives rise to primary root whereas the plumule gives rise to aerial shoot.

The number of cotyledons or seed leaves may be one as in monocotyledons or two as in dicotledons.sometimes, they store reserve food materials eg. Gram, Pea, Almond, Cashewnut, etc. or serve as photosynthetic organs in young seedling. the part of embryonic axis between the radicle and the point of attachment of cotyledons is called **hydocotyl.** Similarly, the part of embryonic axis between the plumule and the point of the attachment of cotyledons is called **epicotyl.**

Example for Dicot seed is Bean, Cicer, Tramarind etc. (Fig-3.46)

Example for monocot seed is paddy, maize etc. (Fig-3.47)

SELF-EVALUATION

One Mark

Choose the correct answer

1. Micropyle occurs in
   a. Ovary b.Seeds c.Ovule d. Both (a) and (c)

2. The Micropyle in a seed helps in the entry of
   a. Water b. Male gamete c. Pollen tube d. None of these

3. Single cotyledon of a monocot seed is
   a.Plumule b. Epicotyl c. Scutellum d. Coleorrhiza

Fill in the blanks

1. Triple fusion occurs between male gamete and ....
2. the outer coat of seed is called ....

Two Marks

1. What is meant by tegmen?
2. What is cotyledon?

Five Marks

1. Differentiate dicot seed from monocot seed.

3.b. Types of Seed Germination

The process by which the dormant embryo of the seed become active growth and forms a seedling or a young plant capable ofindependent existence is called seed germination.

Process of seed germination

Most seeds geminate, when they are provided with water, oxygen and their dormancy is over. The main step of seed germination are described below.

1. Imbibition

The first step in germination is imbibition or uptake of water by the dehydrated seed. The seeds, when placed in moist soil, absorbs water through micropyle. Imbibition causes the seed to swell as the cellular constituents are dehydrated. Imbibition takes place iwth great force. It ruptures the seed coat and enables the radicle to emerge. It causes swelling of seeds and development of the great force called imbibition pressure. Dry seeds packed in a bottle containing water can crack it as they imbibe water and swell.

2. Respiration

Imbition makes the embryo cells active and causes resumption of metabolic activities. Their respiration isinitially anaerobic. The cells possess some simple polysaccharides for functioning as respiratory substrate. When the anaerobic respiration reaches a peak,mitochondria differentiate in the embryo cells. The respiration now becomes aerobic as oxygen starts entering the seed coats.

3. Mobilization of reserve food

The activated embryo cells induce the production of hormones and digestion of reserve food. Depending on the nature of seed, the resouce may be stored chiefly in the endosperm(e.g.castor, cereal grains and other monocots) or in the cotyledons(eg. many dicotyledonssuch as pea, gram, bean etc.) The cells which are rich in proteins produce and secretes hydrolyzing enzymes. These enzymes bring about the digestion of the reserve foods. The latter are changed into sugars, amino acids and other soluble substances. They are translocated to the embryo.

4. Growth of embryo

On the receipt of soluble food, the cells of embryo axis undergo division and expansion. the radicle end of the embryo axis is the first to enlarge. It grows out of

the seed coats and passes downwardly into the soil toestablish itself as the primary root. The plumule also comes out of the seed and soil to establish itself as shoot.

Types of seed germination

It is of two types.Epigeal and hypogeal.

Epigeal germination

In this type of germination, the cotyledons are brought above the ground due to rapid elongation of hypocotyl. Epigeal germination seen inmany dicotyledon seeds such as bean, castor, sunflower, gourd, cucumber etc., During this germination the hyphocotyl grows actively and become curved. It brings the seed above the soil. After coming above the surface of the soil, the hypocotyl straightens. The loosened seed coat fall down and the cotyledons become green. Now, the epicotyl grows and plumule gives rise to green leaves. The cotyledons fall down ultimately.

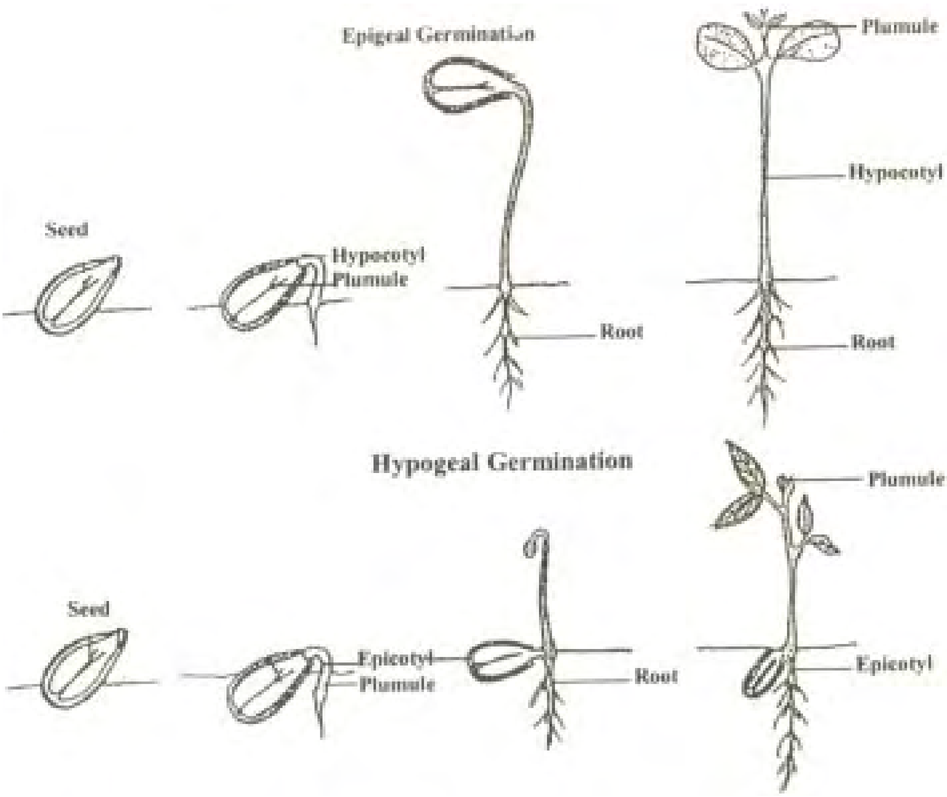


Fig.6.22 Types of seed germination

Hypogeal germination

In this type of germination, the cotyledons remain below the soil due to rapid elongation of epicotyl. It is found in many dicotyledonous seeds and monocotyledonous seeds. During this germination, the epicotyl elongates and become curved. It brings the plumule above the soil. Cotyledons remain underground. In case of monocotyledonous seeds like maize, the coleoptile (plumule covering) grows straight into the soil and comes out to form the green tube. Plumle elongates as well and comes out of the soil while contained in the coleoptile. the plumle ruptures the coleoptile with further growth. The coleorrhiza (covering of radicle) along with radicle grows downwards. After sometimes coleorrhiza ruptures due to further growth of the radicle. The radicle forms the primary root which is soon replaced by fibrous foot.

Special type of Germination

Vivipary

Vivipary is the special type of seed germination. During germinatin, seed is till attached to parent plant and nourished by it. Vivipary generally occurs in mangrove plant. The mangrove plants are generally medium sized tree which grow in salty marshes of sea coasts. (eg.***Rhizophora, Sonneratia, Avicennia***).The seeds of mangrove plants cannot germinate on themarshy habitat because of the excessive saltconcentration and lack of oxygen. The embryo of the seed continues growth while stillattached to parentplant. The radicle of the plant elongates considerably and projects out of the fruit. The lower part of the radicle becomes thick and swollen. Finally, dart like seedling breaks off the parent plant due to its incresing weight and gets embedded into the marsh in such a position that the plumule remains outside the satish water. The radicle immediately formsnew roots and establishes the seedling as a new plant.

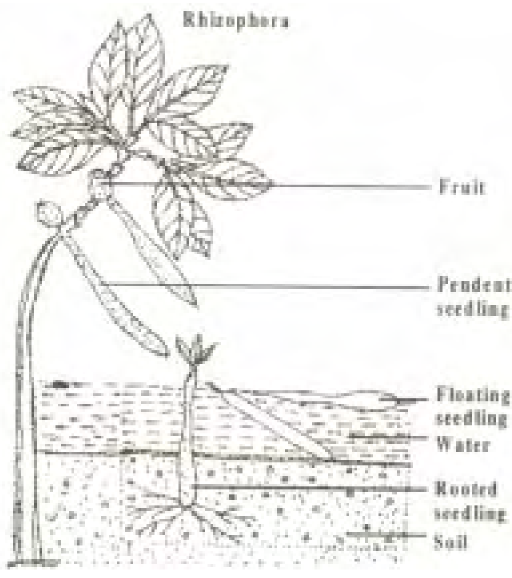


Fig.6.23 Vivipary

Factors necessaryf for seed gamination

A number of factors are required for the process f germination . They are of two types-external and internal.

External factors.

1. Water

Seeds are generally highlly dehydrated with only 6-15% of water content in their cells.Therefore they have low physiological activity. Water provides sufficent hydration to the concentrated protoplasm of the transport gases, a cause hydrolysis of reserve food nd its trnansport and allow embryo cells to grow in size.

2. Oxygen

Oxygen is essential for aerobic respiration to release energy for the metabolic activities. Therefore, with the exception of the few plants. (eg. rice, Typha etc) seeds usually require oxygen or good aeration for their germination.

3. Temperature

Seeds require a definite temperature range withinwhich they germinate. Commonly seeds germinate within temperature range of 5^0C to 40^0C. However, the optimum temperature or seed germination lies between 25-30^0C for most of the species.

4. Light

Light is not an essential factor for the germination of most of the seeds. However some are light sensitive and their germination is influenced by the presence or absence of light.

Internal factor

1. **Maturity of embryo:** The seeds of some plants, when shed, contain immature embryo. Such seeds germinate only after maturation of their embryo.
2. **After ripening:** The freshly shed seeds of some plants may not possessthe required hormones for the growth of embryo, such seeds germinate only after the maturation of their embryo.
3. **Viability:**Usually seeds remain viable or living only for a particular period. The viability of seeds range from a few days (eg. Oxalis) to more than one hundred years. (eg. Trifolium). Maximum viability (i.e., 1000 years) has been recorded in lotus seeds. Seeds germinate only within the period of viablity.

4. **Dormancy:** Seeds of many plants are dormant at the time of shedding. Seed dormancy may be due to various reasons like impermeability, toughness of seed coats, presence of growth inhibitors etc. Such seeds germinate only after natural breakage of dormancy.

SELF -EVALUATION

One Mark

Choose the best answer

1. Hypogeal germination ofalbuminous seed is seen in
   a.Maize b.Castor c.Gram d.Bean
2. Vivipary is a characteristic feature of
   a.Mesophytes b.Halophytes c.Xerophytes d.Hydrophytes.
3. Germination of the seed is promoted by
   a. Green light b.Red light c.Blue light d.Infra red light

Fill in the blanks

1. The phenomenon of germination of seeds inside the fruit itself is called........

2. The inner thin, membranous, whitish integument seen in dicotyledonous seed is known as ....

3. Albuminous seeds store food materials in..............

Two Marks

1. What is funicle?
2. What is hypocotyl?
3. Define epicotyle.

Five Marks

1. Write the difference between epigeal and hypogeal germination.

Ten Marks

1. Describe the epigeal type of seed germination.
2. Describe the hypogeal of seed germination.

3.c. Abscission and Senescence

The process of separation of leaves, flowers, and fruits from the plant is called abscission. It is essential, when these parts are removed that the plant seals off its vascular system to prevent loss of water and nutrients and to exclude bacteria, fungal sporesand other pathogens. An abscission zone, a layer of specialized cells is formed at the base of each part before it is lost, to separate it form the main body. The cells in this layer die and become hardened by the deposition of ligning and suberin. So, by the time the leaf or fruit drops, the vascular system has been sealed off.

Mechanism of Leaf abscission

It takes place at the base of the petiole which is internally marked by a distinct zone of few layers of thin-walled cells arranged transversally across the petiolar base. This zone is called as the **abscission zone** or **abscission layer** (Fig). The cells of the abscission layer is separate from each other due to the dissolution of middle lamella and also the primary cellulose walls under the influence of the increased of the increased activity of the enzymes **pectinase** and **cellulase.** At this stage the petiole remains attached to the stem only by vascular elements and very soon due to its own weight and

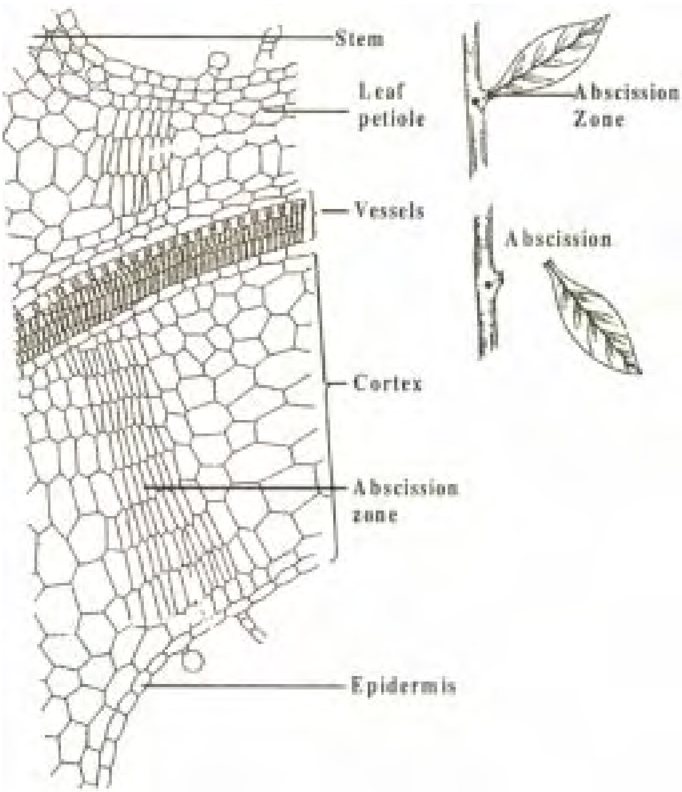


Fig.6.24 A leaf petiole showing the abscission zone

pressure of wind, is detached from the stem. The broken vascular elements are soon plugged with tyloses or gums.

Abscission is controlled by **abscisic acid** (ABA), a growth regulator synthesized primarily in chloroplasts. It is a general inhibitor of many processes, and the abscission layer forms and hardens under its direction.

Importance of Abscission

1. Itsheds off the senescent and dead parts of the plants.
2. It also sheds off ripe fruits, which helps in their dispersaland further life cycle of the plant.
3. In lower plants, shedding of vegetative parts, such as gemmae or plantlets helps in vegetative propagation.

Senescence

As the young plant grows, it undergoes ageing and develops into mature plant in an orderly fashion. The later part of the developmental process which ultimatelyleads to death is called senescence.

Senescence may be defined as the period between reproductive maturity and death of a plant or a part of it. It is characterized by a collective, progressive and deteriorative developmental process which ultimately leads to completeloss of organization and function of the plant or parts of it. The study of plant senescence is called **phytogerontology.**

Types of Senescence

Leopold(1961) has recognized 4 types of senescence patterns, which are as follows:-

1. Whole plant senescence
2. Shoot Senescence
3. Sequential senescence of Organ senescence
4. Simultaneous senescence

1. Whole plant senescence

It is found in monocarpic plants which produce flower and fruit only once in their life cycle. The plants may be annual(e.g. **rice, wheat, gram, mustard** etc.), biennials(e.g.**cabbage, henbane**) or perennials (e.g. certain **bamboos**). The plant dies soon after ripening of seeds.

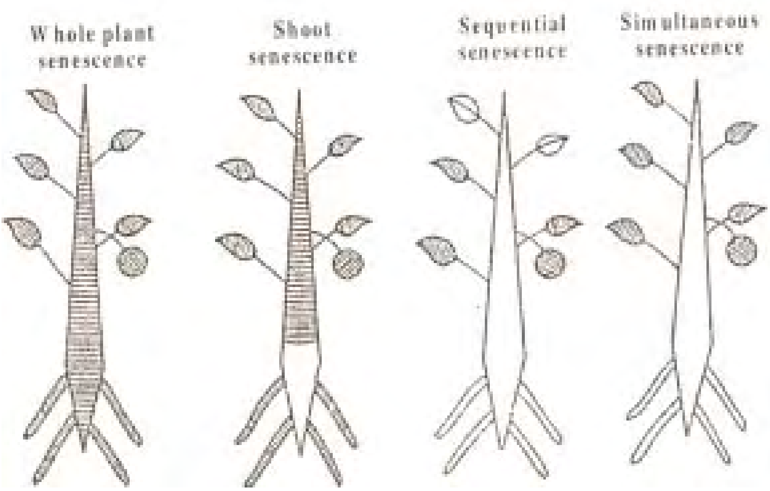


Fig.6.25 Types of senescence

2. Shoot senescence

This type of senescence is found in certain perennial plants which possess underground perennating structures like rhizomes, bulbs, corm etc. The above ground part of the shoot dies each year after flowering and fruiting, but the underground part (stem and root) survives and puts out new shoots again next year. E.g.**banana, gladiolus, ginger** etc.

3. Sequential Senescence

This is found inmany perennial plants in which the tips of main shoot and branches remaining a meristematic state and continue to produce new buds and leaves. The older leaves and lateral organs like branches show senescence and die. Sequential senescence is apparent in evergreen plants. e.g.***Eucalyptus, Pinus*** etc.

4. Simultaneous or Synchronous senescence

It is found in temperate deciduous trees such as **elm** and **maple**. These plants shed all their leaves in autumn and develop new leaves in spring. Because of this shedding of leaves, autumn season is also called fall. Such a senescence of leaves or plant organs is called synchronous.

Physiology of senescence

The process of senescence involves a number of structural and physiological changes in the senescing organs. Some of the important changes are:

i) Cells undergo reduction in their size.
ii) The membrane bound sub-cellular inclusions are disrupted.
iii) Photosynthesis is reduced and starch content decreases in the cells.
iv) Breakdown of chlorophy II is accompanied by synthesis and accumulation of anthocyanin pigments.
v) Protein synthesis is decreased and protein break down enhances.
vi) Amino acids are withdrawn from senescing leaves and transported to the growing regions.
vii) RNA content is decreased.
viii) Chromatin material changes its property and DNA molecules degenerate.

Importance of senescence
Biologically senescence and death have following advantages

1. It maintains efficiency since the old and inefficient organs are replacedby young efficientparts like leaves, buds, flowersand fruits. etc.,
2. During senescence, the celluar breakdown results in release of many nutrients including amino acids, amides, nnucleotides, simple sugars and minerals. The same are withdrawn from the senescing organs into the main trunk and later utilized in the growth and development of new parts.
3. Shoot senescence is a mechanism to help the plants perennate during the unfavorable periods.
4. Simultaneous or synchronous leaf fall occursin autumn prior to winter. It reduces transpiration, which is essential for survival in winter, when the soil is frozen and roots cannot absorb water.
5. Liter of fallen leaves and twigs is an important source of humus and mineral replenishment for the soil.

SELF-EVALUATION
One Mark
Choose the correct answer

1. Which one of the following generally increases during senescence?
a.Protein b.Chlorophyll c.Photosynthesis d.Respiration

2. Senescence of detached leaves can be delayed by the use of
a.Auxin b.Giberellin c.Cytokinin d.Ethylene

3. Yellowing and shedding of leaves in autumn in many trees is an example of

a.Over all senescence b.Deciduous senescence

c.Top senescence d.Progressive Senescence

Fill in the blanks

1. Cytokinins can ....ageing of plant organs.
2. Leaf fall starts, when the amount of .... decreases.

Two Marks

1. Define senescence in plants.
2. What are the four kinds of senescence?
3. What is the significance of senescence in the life of a plant?
4. What is abscission?

Five Marks

1. Describe various types of senescence

Ten Marks

1. Describe the anatomical and biochemical changes taking place during abscission of a leaf.

VII. ENVIRONMENTAL BIOLOGY

1. Organisms and their Environment

The living organisms and the environments in which they live play a complex interdependent and interrelated role. Ecology deals with the various principles that govern the relationships between the organisms and environment. The term **Ecology** (Gk. Oikos-house or place to live, logos-study or discourse) was first introduced, by **Reiter** (1885). **E. Haeckel** (1886) a zoologist defined ecology as 'the study of the reciprocal relationships between organisms and their environment'.

The term 'environment' means surroundings, in which the organisms live. Any constituent or condition of the environment which affects directly or indirectly the form or functioning of the organism in any specific way is called environmental or ecological factor. The environment consists of different types of environmental factors such as light temperature, humidity, precipitation, wind, physical and chemical nature of soil, plants, animals. etc.

The adaptations of the organisms allow them to live in perfect harmony with their surroundings.

Environmental factors

All living organisms, including human beings live in some sort of abiotic component of environment, that contains matter and energy. Various environmental factors can be divided into following two groups:

1. Climatic factors 2. Edaphic factors 3. Biotic Factors. The former two factors are abiotic components that contain matter and energy.

I. Climatic Factors

These are related to the aerial environment of the organisms e.g. light, precipitation, temperature, atmospheric humidity, wind, etc.

II. Edaphic Factors

They include the factors related to the soil. e.g. soil composition, organic matter, soil water, soil air, soil organisms etc.

1. Climatic Factors

i) Light

Light is a factor of great physiological importance. It affects structure, growth and activities of organisms

Sunlight is the source of energy for all organisms. Light is essential for photosynthesis, a process by which green plants synthesise their food on which rest of the living world depends.

Development of photosynthetic pigments, pigments for floral colour, red – far red absorbing phytochrome pigments which regulate morphogenetic processes, induction and regulation of many enzymes are all light regulated processes. "Photoperiod" is an important factor in the flowering of plants.

ii) Temperature

Most living organisms can survive only in a narrow range of temperature (5^0-35^0C). However, there are notable exceptions to it. Certain bacteria, cyanobacteria (blue green algae), seeds, spores and encysted protozoans can occur in hot springs or in very low temperature. Many organisms have developed physiological and behavioural adaptations to avoid extremes of temperature.

Temperature varies in various quarters of the earth according to latitute and altitude. It is also influenced by plant cover, atmospheric humidity, water reservoirs, air current and snow. According to the change of temperature with the increase of latitude, various vegetation zone have been recognized. Similarly , on the basis of change in temperature due to altitude, many vegetation zones can be observed.

iii) Water

Water is an essential requirement of life. No life can exist without water. The protoplasm of the cell contins 80-90% of water. The requirement of water varies from organism to organism. The distribution of organisms depend upon the extent of the need and special **adaptations** for conserving water. Plants of dry area are called **xerophytes**. They develop modifications to increase water absorption, reduce transpiration and store absorbed water.

Plants of aquatic habitats are called **hydrophytes**. They possess aerenchyma (air containing parenchyma) to support themselves in water. The depth, salt content, clarity and water currents determine the growth and distribution of plants in water.

iv) Air

Air currents determine the weather conditions and also affect living organisms, particularly plants. Wind helps in pollination and dispersal of fruits and seeds of many plants. It increases transpiration, which may lead to desiccation and wilting of many plants. Strong winds uproot the plants and cause lodging (flattening of plants on the ground) of many crops. Areas frequented by unidirectional winds develop flag trees, which have branches on one side only. Persistent strong winds restrict the height of plants due to excessive loss of water by transpiration. The plants of such areas usually possess strong spreading roots and strong but flexible shoots.

II. Edaphic Factors

i) Soil

Soil is the upper weathered and humus (organic matter) containing layer of the earth, which sustains plant life and contains numerous living organisms along with their dead remains. Soil provides water, mineral salts and anchorage to plants. The characteristics of soil such as its constitution, origin, temperature range, water holding capacity, aeration, minerals, etc. determine flora and fauna of a particular place.

A productive, well aggregated soil is composed of mineral matter (derived from parent rocks as a result of weathering), organic matter, water and air.

ii) Mineral Matter

The physical attributes of the soil are due to the size of the soil particles. The different particles which are present in the soil vary in their size and depending on this as the soils have been classified into sandy soils (sand with poor representation of silt and clay), loam soils (fine sand with well representation of silt and clay), silt soils (more silt than sand and clay) and clay soils (soils with high percentage of clay).

Sandy soils are porous and hence well aerated but they have very little water holding capacity and are chemically inert. Clay soils have a greater capacity of retaining water and are rich in nutritive salts. They are, however badly aerated. The loam soils are ideally suited for plant growth because they possess appreciable porosity or aeration, sufficient nutritive salts and good water retaining capacity.

iii) Organic Matter

The organic matter (humus) is highly important for all types of soils because it increases both aeration and hydration. It maintains the structure of the

soil and also provides inorganic salts and some growth promoting substances to the soil.

iv) Soil Water

Soil water is of paramount importance in the physiology of plants. It occurs in various forms, such as gravitational, capillary, hygroscopic and combined water. Rain is the principal source of water for the soil. Water which flows down due to the force of gravity is known as **gravitational water**. The gravitational water is not available to the plants. However, it is a big soil water reservoir and is trapped out through tube wells.

A certain amount of rain water is retained within the intercellular spaces of the soil particles in the form of a capillary network. It is called **capillary water** and is used by the plants. Some water molecules form a thin sheet of water around soil particles. It is called **hygroscopic water** (water of imbibition). The hygroscopic water is also not absorbed by the plants. The water, which is bound up in chemicals is called **combined water** or crystalline water. (e.g. $MgSo_4.7H_2O$). It is not available to plants.

The total water present in the soil is called as **field capacity**. Addition of water beyond field capacity causes water logging. It excludes soil air and thus inhibits plant growth. The soils that have poor water holding capacity, cannot afford luxuriant vegetation. In such soils, the plants generally show wilting of their leaves.

v) Soil Air

It is essential for the growth of root and micro-organisms. A badly aerated or water-logged soil will have more of carbon dioxide and lesser amount of oxygen.

vi) pH (Hydrogen ion concentration).

Most organisms thrive in an optimal pH range, pH of soil and water has a strong influence on the distribution of organisms. Some plants and aquatic animals require acidic conditions, others need neutral or alkaline conditions.

vii) Mineral elements.

A number of minerals are essential for normal growth of organisms. Their availability and concentration control the distribution of microbes, plants, and animals. Deficiency or absence of anyone, results in abnormal growth. Excess of mineral is equally harmfull. Plants growing in nitrogen deficient soils have developed special adaptations for obtaining it. For example, leguminous plants harbour nitrogen fixing bacteria in root nodules and the insectivorous plants have

devices to trap insects and absorb nitrogen from their bodies. The salts of calcium, magnesium and phosphorus are most important for aquatic forms. Salinity of soil and water greatly affects the distribution of organism..

III. Biotic factor

The biotic factor deals with interaction among living organisms. This along with abiotic component, forms the overall ecosystem.

Under natural situations, organisms live together influencing each other's life directly or indirectly. Vital processes such as growth, nutrition and reproduction depend very much upon the interactions between the individuals of same species and different species. Pollination, seeds and fruits dispersal, grazing, parasitism and symbiosis are the common examples of such interactions.

Relationships among Organisms

Most of the ecologists are in favour of the use of the term **symbiosis,** which literally means 'living together', in its broader sense.

Odum (1971) used the term 'symbiosis' in its broader sense and preferred to group all the types of symbiotic interactions into two major groups. These are:

1. Positive Interactions

A type of interaction, where populations help one another, the interaction being either one-way or reciprocal. Their benefit may be in respect of food, shelter, substratum, transport etc. These include (i) commensalisms (ii) Protocooperation and (iii) Mutualism.

2. Negative Interactions

Where members of one population may live at the expense of members of the other population compete for foods, excrete harmful wastes, etc. These include (i) Competition, (ii) Predation, (iii) Parasitism, and (iv) Antibiosis.

Positive Interactions

1) Mutualism

Here both the species derive benefit. The two populations enter into some sort of physiological exchange. The following are some common examples of mutualism.

i) Symbiotic Nitrogen fixers

This is a well known example of mutualism, where the bacterium **Rhizobium** form nodules in the roots of leguminous plants, and lives symbiotically with the

host. Bacteria obtain food from the higher plant and in turn fix gaseous nitrogen, making it available to plant.

ii) Mycorrhizae

A symbiotic association between a fungus and a root of a higher plant is called Mycorrihza, which may be (i) **Ectotrophic**, where fungal hyphae are natural substitute of root hairs absorbing water and nutrients from soil e.g. Pines and Oaks or (ii) **Endotrophic**, where fungi occur internal to root tissue. e.g. Orchids and members of Ericaceae

iii) Lichens

These are examples of mutualism where contact is close and permanent as well as obligatory. Their body is made up of a matrix formed by a fungus, within the cells of which an alga is embedded. Usually the fungal groups are from Ascomycetes or Busidiomycetes and the algal groups are species of blue greens. The algal groups takes up the photosynthetic function. The fungal groups are concerned with reproduction. The fungus makes moisture as well as minerals available, whereas alga manufactures food. Neither of the two can grow alone independently in nature. Lichens grow abundantly on bare rock surfaces.

2) Commensalism:

Commensalism refers to association between members of different species only. One is benefited without any effect on the other. Some common examples are:

i) Lianes

Lianes are common in dense forests of moist tropical climates. They maintain no direct nutritional relationship with the trees upon which they grow. On the basis of the type of device used for climbing their support, lianes may be leaners, thorn lianes, twiners or tendril lianes. Common lianes are species of ***Bauhinia, Ficus*** and ***Tinospora.***

ii) Epiphytes

Epiphytes are plants growing perched on other plants. They use other plants only as support and not for water or food supply. They differ from lianes in that they are not rooted into the soil. Epiphytes may grow on trees, shrubs, or larger submerged plants. They grow either on the trunks or leaves. Epiphytes are most

common in tropical rain forests. Many ***orchids, Usnea*** and ***Alectoria*** are well known epiphytes.

iii) Epizoics

Some plants grow on the surfaces of animals. For example, green algae grow on the long, grooved hairs of the sloth. Similarly, ***Basicladia*** (Cladophoraceae) grows on the backs of freshwater turtles.

Negative Interactions

These include the relations, in which one or both the species are harmed in any way during their life period. Some (Clarke, 1954) prefer to call such types of associations as ‘antagonism’. Such negative interactions are generally classified into three broad categories, as **exploitation, antibiosis** and **competition** which are discussed in detail as follows:

I) Exploitation

Here one species harms the other by making its direct or indirect use for support shelter, or food. Thus exploitation may be in respect of shelter or food.

1. Shelter

The so-called ‘parasitic birds’ as cuckoo and cowbird never build their own nests and female lays eggs in the nest established by birds of another usually smaller species.

2. Food

The various relationships in respect of food may belong to:

a) Parasitism

A parasite is the organism living on or in the body of another organism and deriving its food more or less permanently from its tissues.

There are some parasitic vascular plants. Species of ***Cuscuta*** (total stem parasites) grow on other plants on which they depend for nourishment. Young stem twines around the host stem from which adventitious roots develop that finally penetrate the stem of the host, establishing relationship with its conducting elements. The specialized roots are called **haustoria.**

Other examples of such association are total root parasites as ***Orabanche,*** and ***Epifagus*** (Orobanchaceae) which are found on roots of higher plants. ***Rafflesia*** is found on roots of ***Vitis.*** Members of the family Loranthaceae *(Viscum album, Loranthus sp)* are partial stem parasites. They grow rooted in branches of host

trees. Others like ***Santalum album,*** are partial root parasite. Their roots are attached to host plants. Majority of parasites are microorganisms, of which fungi, bacteria, mycoplasmas, rickettsias and viruses parasitise plants as well as animals.

b) Carnivorous Plants

A number of plants as ***Nepenthes, Darlingtonia, Drosera, Utricularia, Dionaea*** consume insects and other small animals for their foods. They are also known as insectivorous plants. They are adapted in remarkable ways to attract, catch and digest their victims. Their leaves or foliar appendages produce proteolytic enzymes for digestion of the insects. The carnivorous habit in plants is said to be an incidental feature of their nutrition, since they possess green leaves and carryout photosynthesis.

II) Antibiosis

The term 'antibiosis' generally refers to the complete or partial inhibition or death of one organism by another through the production of some substance or environmental conditions as a result of metabolic pathways. Here none of them derives any benefit. These substances and or conditions are harmful (antagonistic) to other organism. The phenomenon of antibiosis is much common among microbial world. Production of chemicals that are antagonistic to microbes – the **antibiotics** is well known.

Bacteria, actinomycetes and fungi produce a number of antimicrobial substances which are widespread in nature. Antagonistic substances are also reported in some algae, as for example in cultures of ***Chorella vulgaris,*** some substance accumulates which inhibits the growth of the diatom, ***Nitxschia frustrulum***. Pond 'blooms' of blue-green algae especially ***Microcystis*** are known to produce toxins such as hydroxylamine which causes death of fish and cattle.

The term antibiosis would also include such phenomena as **hypersensitive reactions** that involve the interaction between microorganisms, particularly pathogenic ones, and harmful to one or both.

III) Competition

Competition occurs when individuals attempt to obtain a resource that is inadequate to support all the individuals seeking it, or even if the resource is adequate, individuals harm one another in trying to obtain it. The resources competed for can be divided into two types :

(i) Raw material such as light, inorganic nutrients, and water in autotrophs and organic food and water in heterotrophs.

(ii) Space to grow, nest, hide from predators. etc.

The competition may be

(i) Intraspecific: Occurring between members of the same species of the population.

(ii) Interspesific: Occurring between different species of population. Competition thus is usually between members of the same trophic level.

Self evaluation

One Mark

Fill in the blanks

1. Light is necessary for plants to do ______________
2. Soil provides water and ________to plants.

Two marks

1. Write short note on soil water.
2. What is symbiosis?
3. What are Mycorrhizae?
4. What are lichens?
5. What is competition?

Five marks

1. Describe the effects of edaphic factors on the living organisms.
2. Give an account of the effect of light and temperature on the plants.

2. Hydrophytes, Mesophytes and Xerophytes

The living organisms live in habitats which provide them with what they need. The organisms have to be well fitted to their environments in which they live. Any characteristic that is advantageous to a particular organism or population is an adaptation. The term 'adaptation' can be defined as *' the structural and functional characteristics of the living organisms which develop over a period of time and enable them to survive and reproduce in a particular environment or habitat.'* The living organisms live in three main types of habitats**- water, land** and **air,** and exhibit various types of adaptations.

Warming (1909) classified the plants on the basis of their water requirement into three ecological groups. They are

1. Hydrophytes
2. Xerophytes
3. Mesophytes

Hydrophytes

Hydrophytes are plants that grow in regions, where, there is plenty of water supply (ie. Pond, pool, lake, river and marshes) or wet soils.

The organisms found in aquatic habitats i.e. sea (**marine** habitat), lakes and ponds (**lentic** habitats) and streams and rivers (**lotic** habitats) experience a variety of physical factors. These include, the availability of oxygen and light, pressure fluctuations, resistance to motion, salt concentration, etc. To adjust to the prevailing conditions, aquatic plants have various types of adaptations.

Classification of Hydrophytes

According to their relation to water and air, the hydrophytes are grouped into four categories.

1. Free floating hydrophytes.
2. Floating but rooted hydrophytes.
3. Submerged hydrophytes (floating and rooted).
4. Amphibious hydrophytes.

1. Free floating hydrophytes

These plants float freely on the surface of water but are not rooted in the soil. These plants are in contact with both water and air **(e.g. *Eichhornia, Pistia, Wolffia, and Lemna*)**

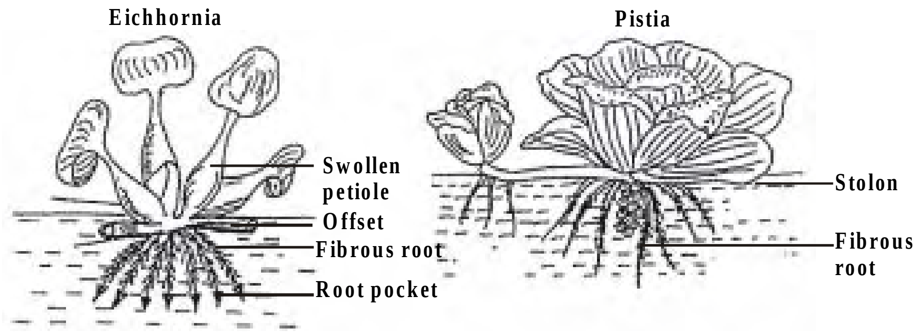


Fig : 7.1. Free-floating hydrophytes

2. Floating but rooted hydrophytes

These hydrophytes are rooted in the mud but their leaves and flowering shoots float on the water surface. **E.g. *Victoria regia, Nymphaea, Nelumbium and Marsilea*.**

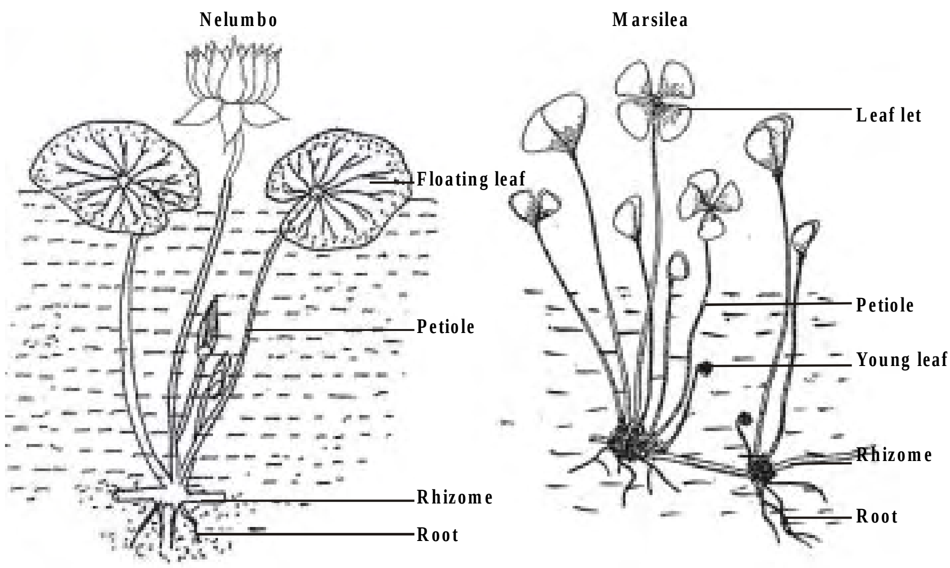


Fig : 7.2. Rooted hydrophytes with floating leaves

3. Submerged hydrophytes (floating)

Plants which grow below the water surface and not in contact with atmosphere are called free floating submerged hydrophytes. E.g. ***Ceratophyllum,*** and ***Utricularia.***

Submerged hydrophytes (Rooted)

These plants are completely immersed in water and rooted in the mud. E.g. ***Hydrilla, Vallisneria, Potamogeton* etc.,**

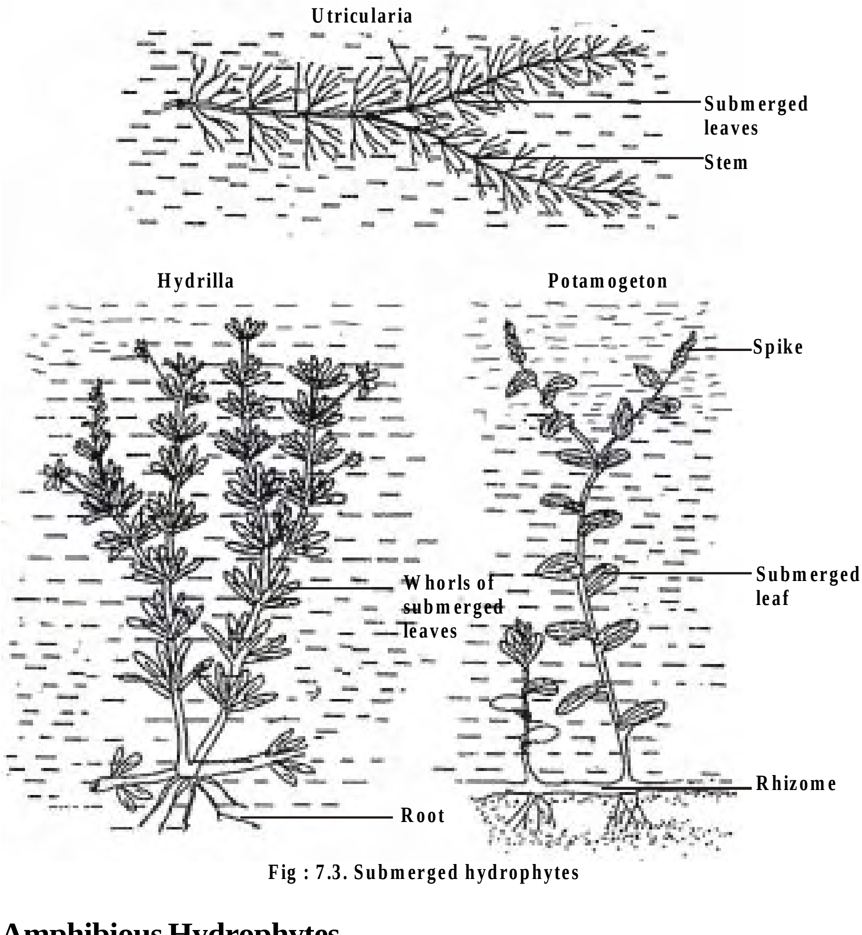


Fig : 7.3. Submerged hydrophytes

4. Amphibious Hydrophytes

These plants grow in shallow waters. Their roots, some part of stems and leaves are submerged in water. But some flowering shoots spring well above the water surface.

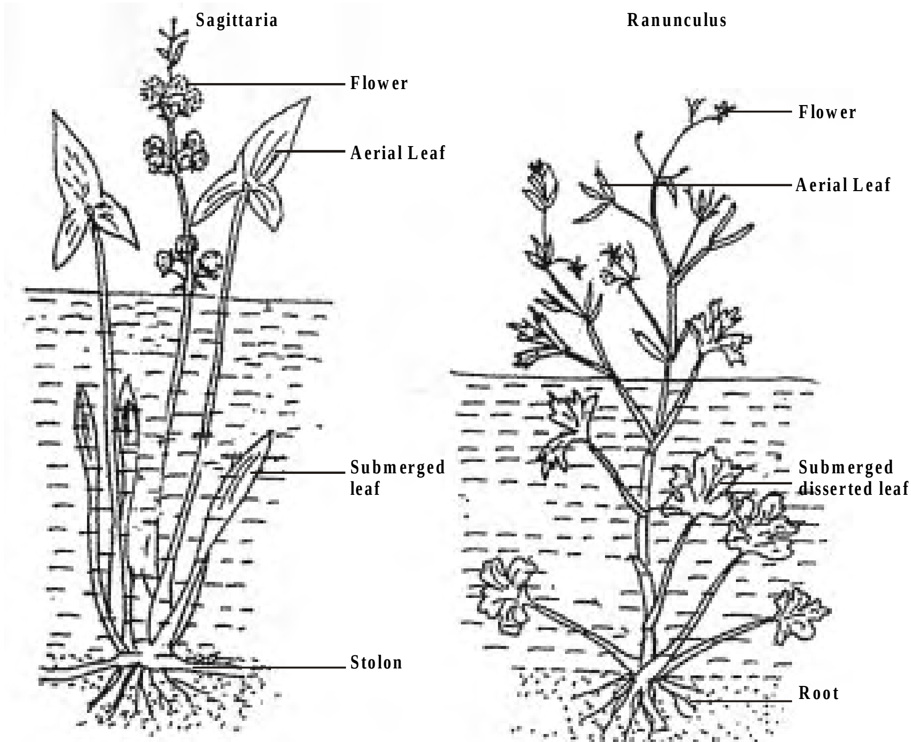


Fig : 7.4. Amphibious Hydrophytes

These plants are adapted to both aquatic and terrestrial modes of life. The aerial parts of these amphibious plants show mesophytic characters, while the submerged parts develop true hydrophytic characters. e.g. ***Limnophylla heterophylla, Typha, Sagittaria*** **etc.,**

Morphological adaptations

1. Root system is poorly developed.
2. Roots of floating hydrophytes show very poor development of root hairs, absence of true root caps, with root pockets to protect their tips from injuries. (e.g. ***Eichhornia*****)**
3. Rooted hydrophytes like ***Hydrilla, Vallisnera, Elodia*** derive their nourishment through their body surfaces. More plants partly depend on their roots for the absorption of minerals from the soil. Roots are totally absent in ***Ceratophyllum, Salvinia, Azolla, Utricularia*** **etc.,**
4. In ***Jussiaea repens*** two types of roots develop. Some of them are normal, while others are negatively geotropic, floating roots, spongy in nature and keep the plants afloat.

5. In free floating hydrophytes, the stem is thick and short, floating on the surface of water (e.g.) ***Eichhornia.***
6. In ***Nymphaea*** and ***Nelumbium*** the stem is a rhizome. These rhizomes live for many years and produce leaves every year.
7. In rooted plants with floating leaves, the leaves are large, flat and entire (e.g.) ***Nymphaea, Victoria regia.*** Their upper surface is coated with wax. The wax coating protects the leaves from mechanical and physical injuries and also prevents clogging of stomata by water.
8. In floating plants of ***Eichhornia, Trapa* etc.,** the petioles become characteristically swollen and become spongy, providing buoyancy.
9. Plants such as ***Limnophylla heterophylla, Sagittaria, Ranunculus, Salvinia, Azolla*** etc show heterophylly, with submerged dissected leaves offering little resistance against the water currents, and absorbing dissolved carbon-di-oxide from water. The aerial leaves show typical mesophytic features. It acts as foliage leaf.
10. Pollination (e.g. Vallisneria) and dispersal of fruits and seeds are accomplished by the agency of water.

Anatomical adaptations

1. The root and shoot systems show common features such as cuticle which is very thin or absent.
2. Epidermis is usually a single layer of thin walled cells, not protective in function.
3. Cortex is well developed. It has numerous air chambers. It helps in buoyancy and rapid gaseous exchange.
4. Mechanical tissues are generally absent.

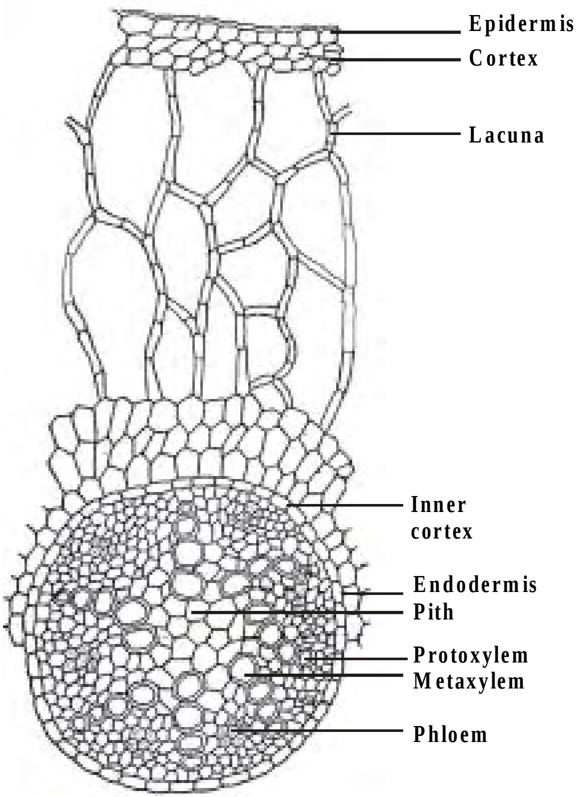


Fig : 7.5. T.S. of Nymphaea root

5. In the vascular tissue, xylem vessels are less common. Only tracheids are present in submerged forms.

6. In amphibious form, the xylem and phloem are well developed (e.g.) ***Limnophylla heterophylla*** or vascular bundles may be aggregated towards the centre. (e.g. ***Jussiaea***)

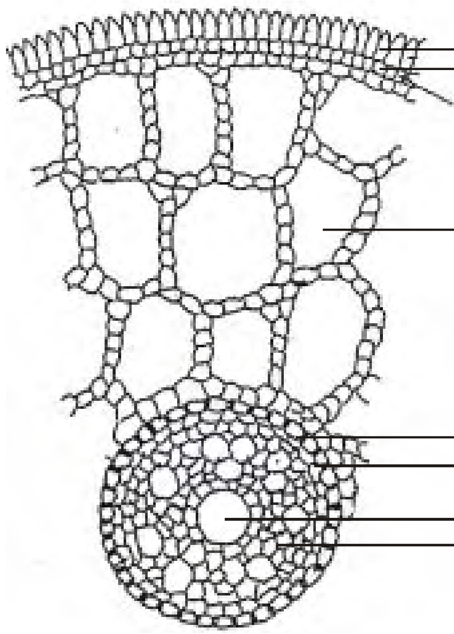


Fig : 7.6. T.S. Hydrilla Stem

7. Epidermal cells of leaves contain chloroplasts and they can function as photosynthetic tissue, especially where the leaves and stems are very thin. eg. ***Hydrilla***

8. Stomata are totally absent in submerged, but in floating leaves, stomata are confined only to the upper surface. In amphibious plants stomata may be scattered on all the aerial parts.

9. In submerged leaves, air chambers are filled with respiratory and other gases and moisture.

10. In Water Lilly (***Nymphaea***) and some other plants, special type of star shaped lignified cells called **asterosclereids** are developed. It gives mechanical support to the plants.

11. The aquatic plants exhibit a low compensation point and low osmotic concentration of cell sap.

12. Mucilage cells and mucilage canals secrete mucilage to protect the plant body from decay under water.

Xerophytes

Plants, which grow in dry habitats or xeric conditions, are called **xerophytes**. Places where available water is not present in adequate quantity are termed xeric habitats, which may be of three types.

1. Physically dry habitats

Where water retaining capacity of the soil is very low and the climate is dry **e.g. D*esert, Rock surface* etc.**

2. Physiologically dry habitats

Places where water is present in excess amount, but it is not absorbed by the plants easily.

3. Physically and physiologically dry habits e.g. **Slopes of mountains.**

Daubenmire (1959) defined xerophytes as "plants which grow on substrate that usually become depleted of water to a depth of at least two decimeters during normal growth season."

Xeric habitats are characterized by

1. High temperature of atmosphere and soil
2. Deficiency of water and minerals
3. Presence of water deep in the soil.
4. High intensity of light

On the basis of morphology, physiology and life cycle patterns, xerophytes are classified into three categories.

1. Drought escaping plants

They are also called as **Drought evaders.** They are mostly found in arid zones. They are annuals, which complete their life cycles within a very short period of 6-8 weeks and thus escape dryness (e.g.) ***Solanum xanthocarpum, Argemone mexicana, Cassia tora* etc.**

2. Drought Enduring Xerophytes (Succulents)

These plants suffer from dryness in their external environment only. Their succulent, fleshy organs (stems, leaves, roots) serve as water storage organs which accumulate large amount of water during the brief raining reason. e.g ***Agave, Aloe, Euphorbia, Opuntia, Asparagus.***

Fleshy Xerophytes

In some plants, stem becomes succulent which are called the **"Fleshy Xerophytes"** as in ***Opuntia*** and ***Euphorbia***.

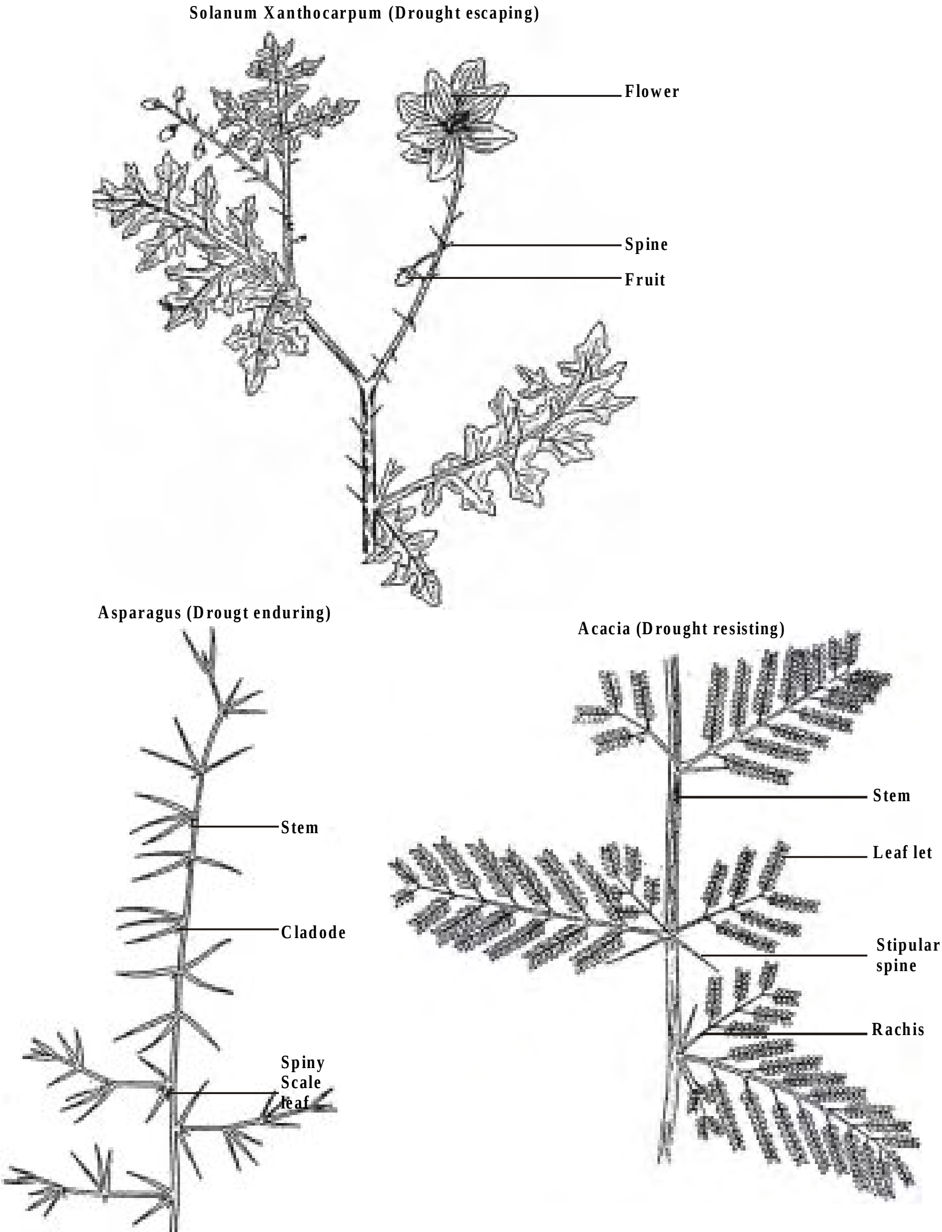


Fig : 7.7. Xerophytes

Opuntia dilleni

It is a wild spiny shrub of a rid places. The flattenned, green stem segments called **phylloclades** are thick and fleshy and carry out the function of photosynthesis. The phylloclades contain lot of mucilage, which help in retaining water for long a item.

In plants like ***Opuntia dilleni,*** stems are flat without leaves and perform photosynthesis.

3. Drought resisting plants (Non- succulent perennial)

The drought resisting plants are the true xerophytes. They possess a number of morphological, anatomical and physiological characteristics, which enable them to withstand critical dry condition. Thus they suffer from dryness both in their internal as well as external environments. e.g ***Calotropis procera, Acacia nilotica, Zizyphus jujuba, Capparis aphylla, Casuarina, Nerium, Saccharum*** etc.

Morphological Adaptations

1. The root system is very well developed with root hairs and root caps. e.g. ***Calotropis.***
2. The roots are fasciculated as in ***Asparagus***.
3. Stems are stunted, woody, dry, hard, ridged, and covered with thick bark, may be underground, e.g. ***Saccharum***. In ***Opuntia*** phylloclade is covered with spines.
4. Stem is covered with thick coating of wax and silica in ***Equisetum*** or dense hairs as in ***Calotropis***.
5. Stems may be modified into a thorn e.g. ***Ulex*** or cladodes e.g. ***Asparagus.***
6. Leaves are very much reduced, small scale-like, appearing only for a brief period (Caducous) sometimes modified into spines or scales as in ***Casuarina, Ruscus, Asparagus***.
7. Lamina may be narrow or needle like as in ***Pinus*** or divided into many leaflets as in ***Acacia*** or succulents as in ***Aloe***.
8. In ***Euphorbia*** and ***Zizyphus jujuba*** stipules become modified into spines.
9. Xerophytes like ***Calotropis*** have hairy covering on the leaves and stems to check transpiration.

Anatomical Adaptations

1. Root hairs and root caps are well developed in ***Opuntia***.
2. Roots may become fleshy to store water as in ***Asparagus***

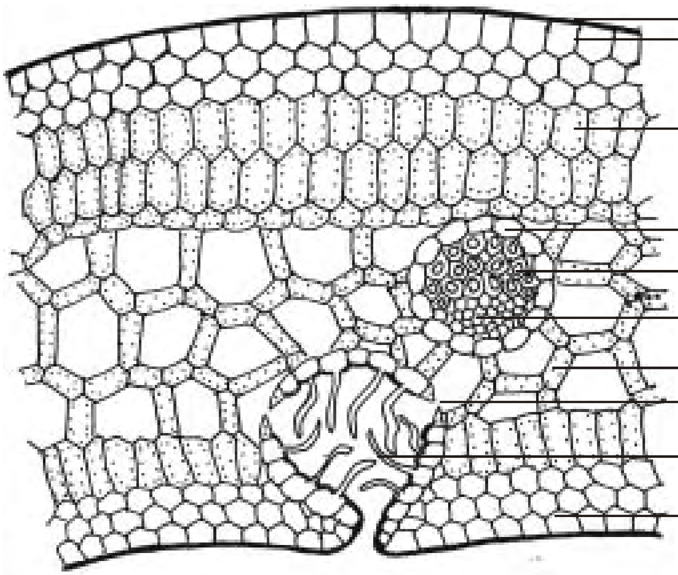


Fig : 7.8. T.S> of Nerium leaf

3. In succulent xerophytes, stems possess a water storage region (thin walled parenchyma cells)
4. Stems of non-succulent xerophytes show a very thick cuticle, well developed epidermis with thickened cell wall, several layered and sclerenchymatous hypodermis e.g. ***Casuarina***.
5. The stems have sunken stomata and well developed vascular and mechanical tissues.
6. Leaves show well developed cuticle, succulent leaves in ***Aloe***, multilayered epidermis in ***Nerium***, sclerenchymatous and several layered hypodermis in ***Pinus***, bulliform cells in Sugarcane.
7. Mesophyll is well differentiated and vascular tissues and mechanical tissues are well developed.

Physiological Adaptations

1. The stomata of these plants open during night hours and remain closed during the day. This unusual feature is associated with metabolic activities of these plants.
2. In xerophytes, the chemical compounds of cell sap are converted into wall forming compounds (eg) Cellulose, Suberin etc.

3. Some enzymes, such as catalases, perioxidases are more active in xerophytes than in mesophytes.
4. The capacity of xerophytes to survive in long period of drought is due to the resistance of the hardened protoplasm to heat and desiccation.
5. The Xerophytes have very high osmotic pressure, which increases the turgidity of the cell sap.

Mesophytes

Mesophytes are common land plants, which grow in situations that are neither too wet nor too dry. These plants can neither grow in water or waterlogged soils nor can they survive in dry places. In other words, mesophytes are the plants of those regions where climates and soils are favourable. Vegetations of forests, meadows and cultivated fields belong to this category. The simplest mesophytic community comprises of grasses and herbs, richer communities have herbs and bushes, and the richest ones have trees (rain-forest in tropics).

Mesophytes can be classified into two main community groups:

1. Communities of grasses and herbs.
2. Communities of woody plants.

Adaptations of plants to mesic habitats. The plants which grow in moderately moist and cool habitats are called **mesophytes** e.g. majority of crop plants. The mesophytes have following morphological and physiological features.

i. Root system is well developed. Roots are generally fairly branched with root caps and root hairs.

ii. The stems are generally aerial, solid and freely branched.

iii. Leaves are generally large, broad and moderately thick. They are without hairs or waxy coating.

iv. The stomata are distributed on both surfaces of the leaves.

v. The mesophyll in leaves is differentiated into palisade and spongy parenchyma, with many intercellular spaces.

vi. The aerial parts possess moderately developed cuticle.

vii. Mechanical and vascular tissues are fairly developed and well differentiated.

Self Evaluation

One Mark

Choose the best answer

1. Finely dissected leaves are common in

   a. Submerged plants b. Amphibious plants
   c. Free floating plants d. Rooted floating plants

2. The root pockets are present instead of root caps in

   a. Utricularia b. Eichhornia c. Hydrilla d. Limnophylla

Fill in the blanks

1. Plants that are growing in water are called _____________
2. Plants that are seen in xeric conditions are known as _______________

Two marks

1. What are hydrophytes?
2. What are the three ecological groups of plants?
3. Define : Xerophytes

Five marks

1. List out the different kinds of hydrophytes with examples.
2. Explain the basis for the classification of xerophytes.

Ten marks

1. List out the adaptations of xerophytes with suitable examples.

3. Natural Resources

Man lives in nature and depends on the resources of nature. The progress of mankind depends upon the exploitation of different natural resources. The utilization of soil, water, coal, electricity, oil, gas and nuclear energy is very important for the development of a nation. These resources have changed the living standards of man. India contains the world's largest resource of coal and third and fourth largest resource of manganese and iron.

The world is facing an ecological crisis and is degrading her natural resources day by day, due to over exploitation. India is no exception.

Food, shelter and clothing are the primary requirements of man. Early human society has used natural resources, relatively in much less quantity to cover its wants.

Natural resources

The word 'resource' means a source of supply or support that is generally held in reserve. The natural resources are the components of lithosphere, hydrosphere and atmosphere. They include energy, air, water, soil, minerals, plant and animals. For man resources are those materials and sources of energy which are needed for survival and comforts.

The nature of resources varies from society to society.

Types of natural resources

Natural resources are classified in different ways. i.e. on the basis of chemical composition, availability and distribution.

A. Natural resources are of three types on the basis of their chemical composition

1. **Inorganic Resources.** eg. *air, water and minerals*
2. **Organic Resources** eg. *plants, animals. micro-organisms and fossil fuels*.
3. **Mixture of Inorganic and Organic Resources,** eg. *soil*

B. Natural resources are of two types depending upon their availability and abundance.

1. Inexhaustible Resources

They are not likely to be exhausted by man's use. They are air, clay, sand, tidal energy etc. Although the air is available in exhaustible quantity, it can be degraded, if its pollution is not checked.

2. Exhaustible Resources

They are likely to be exhausted by human use. They are further of two types- renewable and non-renewable.

a. Renewable Resources

They have inherent capacity to reappear or replenish themselves by quick recycling, reproduction and replacement within a reasonable time. Soil and living organisms are the main renewable resources.

b. Non- Renewable Resources

They lack the ability for recycling and replacement. The substances with a very long recycling time are also regarded as non-renewable resource e.g. fossil fuels like coal, petroleum and natural gas and minerals.

It is important to note that underground water, forests and wild life are regarded renewable resources but become non-renewable, if they are not used properly.

Energy resources

Source: Ecologically man is only a part of energy flow in nature. Man requires energy for his daily needs. The major energy sources are fuel wood, fossil fuels such as coal, petroleum and natural gas. Apart from these, the other direct energy resources are sunlight, hydroelectric and wind power, tidal, geothermal and nuclear energy.

Energy Requirement: During early stages of human civilization, the daily per capita need for energy was just 2,000-4,000 kilo calories. During the agricultural stage, the muscular energy of domestic animals was used for work. The per capita energy consumption gradually increased. In nineteenth century, during the industrial stage of human civilization, the use of fossil fuel started and the per capita energy requirement increased to 70,000 kilo calories per day.

Today we need energy for agriculture, industry, transport, communication, comfort and defence. The per head energy consumption varies from country to country

Depletion of fossil fuels

Today the world's energy resources have reached critical stage. Most of the world's human population uses fossil fuels (coal, petroleum and natural gas). The fossil fuel resources are being rapidly depleted. As a result these resources

may last only another few centuries. The dwindling stocks of fuels has led to the search of alternate sources of energy.

Sources of Energy

Some alternative sources of fuel are solar energy, hydro-electric energy, geo-thermal energy, wind power, tidal energy, energy from garbage, dung energy and nuclear energy. They are generally called renewable/ non- conventional sources of energy.

1. Solar Energy

Sun is an inexhaustible and pollution free source of energy. Solar equipments have been developed to harness sun-rays to heat water, cook meals, light our houses and run certain machines.

2. Nuclear Energy

It is generated by fusion of the atoms of certain elements such as Uranium - 235. The processes results in the release of enormous amount of energy. Fission of 1 amu (atomic mass unit) of Uranium – 235 can generate energy equivalent to that obtainable from burning of 15 metric tons of coal or about 14 barrels of crude oil. In our country atomic power stations have been set up in Tarapur (Bombay), Narora (Uttar Pradesh), Kota (Rajasthan) and Kalpakkam (Tamil Nadu).

3. Wind Power

It has been used for centuries to run the wind-mills for grinding grains and pump water in certain areas. But the wind does not blow with required intensity all the year round and in all areas. Therefore, wind power can be used only in certain areas and on certain days.

4. Dung Energy

Cattle dung is widely used as fuel in rural areas of our country. This deprives our fields of valuable organic manure. Now cattle dung is used in **Biogas** or **Gobar Gas Plant** to produce an odourless, low pressure gas. This gas can be used for cooking and heating. The residue is used as manure.

5. Energy from garbage

The garbage of houses contains waste paper, plastics and several other materials. It can be used to produce electricity.

6. Tidal Energy

Tidal waves of the sea can be used to generate electricity.

7. Geo-thermal Energy

In some places, the heated water comes to the earth's surface as hot springs. It can be used for heating water and building and for generating electricity.

8. Hydro-electric Energy

It is produced from the kinetic energy of water falling from height. A number of power stations have been established on many rivers in our country.

Conservation of Energy

The present critical energy position demands an organized effort at all levels from individual to international action. A considerable amount of energy can be saved by reducing wastage and using energy efficient devices. Following measures can help in this effort:

1. Development of technology for the use of solar energy in appliances and transport vehicles
2. Development of efficient and smokeless **Chulhas** or wood stoves
3. Development of non-conventional energy sources and less dependence on fossil fuels.
4. Planned programme for raising fuel wood, trees and shrubs under the control and maintenance of local communities especially in developing countries.
5. Effective use of agricultural and animal wastes to obtain biogas and manure.
6. Improvement of engine and pump designs to increase fuel efficiency.
7. Development of effective techniques to trap wind and tidal energy.

Forest Resources

Forest is an important natural resource. It is most important natural habitat for wild life. It is also utilized by farmers for commercial and recreational purposes. Many herbivores find shelter and carnivores their prey in the forest. Besides this, forest plays most important role from commercial point of view. Forest based cottage industries, such as bee-keeping, bamboo mat and basket making provides small-scale industry to the tribal people. Sal is a most important source for timber industries. It also provides raw materials for pulp and plywood industry.

Green plants of the forest are food-producing organisms and are primary producers of the “food chain”. These foods are stored in the form of fruits, nuts, seeds, nectar and wood. Therefore, forest serves as an energy reservoir, trapping energy from sunlight and storing it in the form of a biochemical product.

Forest plays a most important role in keeping the atmospheric balance by consuming CO_2 and releasing O_2, the latter which is essential for animal life. So removal of plants and trees would disturb the composition of natural air. An acre of forest absorbs four tonnes of carbonic acid gas and recycles eight tonnes of oxygen into environment.

If a forest is cut down, energy stored in the wood is lost and also most of the nutrients of the system are lost. Such deforestation leaves a poor soil which can support agriculture for only a short time, because the harvesting of the first few crops removes the remaining nutrients and renders it useless. Deforestation causes soil erosion.

The reduction of forests later affects rainfall and thereby restricts the availability of a most important natural resource, the rain water. In natural forests, the tree roots bind the soil and about 90 per cent of the water falling on the forests is retained either in humus or in the plant tissue. The forest thus acts as a soaking device and plays a vital role in the hydrological cycle. It has been estimated that in India 60,000 million tonnes of top soil is carried away annually by rain water from deforested area.

Now-a-days the tendency of deforestation is increasing day by day. Man is cutting forest to get temporary benefits but there is a tremendous loss in due course of time.

Social Forestry

The National Commission on Agriculture is giving serious thought to the problem of deforestation and recommended introduction of “ Social Forestry”. Social forestry may be defined as an additional aid to wild life conservaion. According to K.M. Tewari (President, Forest Research Institute, Dehradun) “Social forestry is a concept, a programme and a mission which aims at ensuring ecological, economic and social security to the people, particularly to the rural masses especially by involving the beneficiaries right from the planning stage to the harvesting stage".

Different components of social forestry programme are

1. Protection and afforestation of degraded forests .
2. Creation of village wood lots on community lands and government waste lands.
3. Block plantation.
4. Argo-forestry (trees along with agricultural crops) on marginal and sub-marginal farm lands.
5. Tree planting around habitation area and field boundaries
6. Tree planting in urban and industrial areas for aesthetic purposes,
7. Control of erosion by planting trees or shrubs.
8. Strip plantation along road sides, canals and rail lines.

Conservation of Forests

Following measures should be adopted to conserve forests:

1. A tree removed from the forest for any purpose must be replaced by a new tree. Thus tree felling should be matched by tree planting programmes as early as possible.
2. Afforestation should be done in areas unfit for agriculture, along highways and river banks around play grounds and parks. A special programme of tree plantation called Van Mahotsav is held every year in our country. It should be made popular and effective.
3. Maximum economy should be observed in the use of timber and fuel wood minimising by the wastage.
4. The use of fire wood should be discouraged and alternative source of energy for cooking such as biogas, natural gas etc., should be made available.
5. Forest should be protected from fire. Modern fire fighting equipment should be used to extinguish accidental forest fire.
6. Pests and diseases of forest trees should be controlled by fumigation and aerial spray of fungicides and through biological method of pest control.
7. Grazing of cattles in the forests should be discouraged.

8. Modern methods of forest management should be adopted. These include, use of irrigation, fertilizers, bacterial and mycorrhizal inoculation, disease and pest management control of weeds, breeding of elite trees and tissue culture techniques.

9. Technique of improvement cutting and selective cutting should be done. The improvement cutting includes the removal of old dying trees, non commercial trees, damage tree and diseased trees. Selective cutting involves cutting of mature timber trees and crowded trees.

Conservation of Water

Water Resources

Underground water is available in the crevices of rocks, and between the soil particles. The layers of earth which contain such water form the underground water table. Only certain depth under the earth will be filled with underground water. The upper surface of such stagnant water is called underground water level. The underground water level will vary from 1-100 mts depending upon the place. The water taken out from the water table is compensated every year through monsoon rain.

Importance of Rain Water

The Rainwater plays a vital role in the water cycle of the earth. Rainwater is the main source for rivers, lakes, and underground water. Nowadays, we depend mainly on the above said water resources for our water needs. In such as situation, the importance of rainwater is not realised much. Rainwater Harvest means understanding the importance of rainwater and using the same in all the catchment areas without wasting.

Reasons for water scarcity

1. The water sources are used to the maximum level in order to meet the needs of the growing population of the cities.
2. The increasing buildings, tar and cement roads occupy the open space and these prevent the percolation of natural rainwater into the earth.
3. The failure of monsoon rains brings about increased water scarcity.
4. Usage of underground water becomes more during poor rainfall.
5. Excessive pumping of underground water reduces the water level and the wells become dry.

6. Rainwater is the only source for all the available water.

Thus, in order to maintain the underground water resources, we have to conserve rainwater in the underground water table. Rainwater Harvest is the only solution to overcome water scarcity.

Rain Water Harvesting

Types of Harvesting Rainwater

Collection of rainwater during rainy season and allowing this water to percolate into the soil is known as rain water harvesting.

1. Rainwater can be harvested in two ways, depending on the rate of rainfall.
2. We can collect the rainwater directly in big troughs and the same when we used when needed.
3. The underground water resources can be improved by introducing special rainwater harvesting systems into the earth.

Rainwater harvesting depends upon the annual rainfall, area of rainwater harvesting and the amount of rainwater that may percolate into the soil.

The average rain fall in Chennai	- 1200mm (1.2 m)
The rain fall in a housing plot of 2400 sq.ft.	- 223 x 1.2 = 267 (cubic metre)
	2,67,000 litres.
Of this the rate of rainwater sent into the earth	- 1,60,000 lit. (per year)

We can avoid water scarcity by sending back 1,60,000 litres of rainwater into the earth through rain water harvesting.

Rainwater can be harvested from the following;

i. The rainwater falling on the open terrace

ii. The rainwater falling on the open space around the buildings.

iii. If a house has well or borewell, the rainwater from the open terrace can be harvested very easily.

iv. The rainwater from the open space can be harvested through a proper rainwater harvesting system.

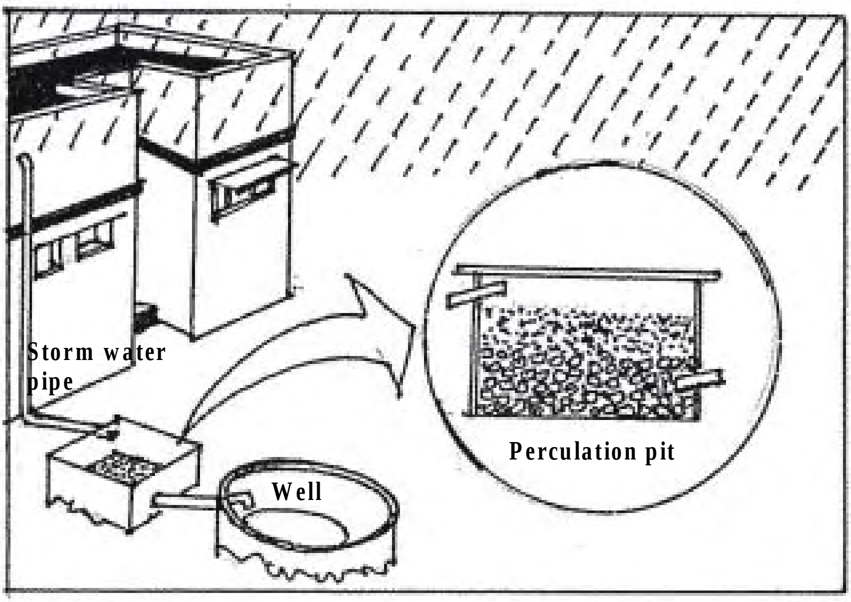


Fig : 7.9. Rain water harvesting from a building

I. Collection of Rainwater from terrace and open spaces.

a. To collect through open wells.
b. To collect through bore wells.

Method of collecting

1. Method of water soaking pits
2. Water soaking pits with perforation
3. Water soaking beds (trenches)
4. Shallow water supplying well
5. Deep water supplying well.

Method to Harvest Rainwater from thatched Roofs/Tiled Roofs

1. The water from the roof can be brought through pipes and sent through sand filters.
2. Polythene sheets can be spread over thatched huts and the water from it can be collected.
3. The water cleaned through sand filter can be saved in troughs and used.

Rain water harvest through open wells

Water falling on the open terrace can be collected through pipes and let into the well or earth level storing trough.

1. The filtering trough should be made as follows.
2. Broken bricks or pebbles are to be laid one feet height at the bottom.
3. The top level of the trough must be filled with river sand.
4. The trough can be closed with a cement slab if necessary.

Rainwater Harvest through Bore Wells

The water falling on the open terrace can be sent into the bore well through pipes and filtering pit.

The filtering trough is to be made as indicated in the diagram.

The overflowing rainwater can be let into the soaking pit

Rainwater also can be harvested through the bore well which are not under use.

Rainwater penetrating level will be lower in the bore well than the open well.

Seepage pit – construction

It can be constructed in the open space around the house.

Pits can be in the form of square / rectangle or a circle.

The pits are to be filled with broken bricks, pebbles and river sand.

This method is suitable for sandy areas.

One such pit is needed for every 300 sq.ft. area.

Seepage pits with perforation

At the centre of the above said soaking pit, a bore well is to be erected.

The bore well must be of 150 – 300 mm radius and 10-15 feet depth.

It is to be filled with the broken bricks and pebbles

This method is suitable for area with clayey soil

One such pit is needed for 3000 sq.ft. area.

Water Soaking Trench

This pit is made in lengthwise direction

Length 3 to 15 feet

Breadth 1 to 3 feet

Depth 3 to 4.5 feet

The Trench is to be filled with broken bricks, pebbles and river sand.

This is suitable for sandy areas.

SELF EVALUATION

One Mark

Choose the correct answer.

1. Deforestation may reduce the chances of

   a. Rainfall b. Land slides c. Soil erosion d. Frequent cyclones

2. Soil erosion can be checked by

   a. Wind screen alone b. Restricted human activity
   c. Checking movement of animals d. Good plant cover

3. Common sources of energy used in Indian villages is

   a. Electricity b. Sun c. Coal d. Wood and animal dung

4. Which of the following is non- renewable?

   a. Water b. Coal c. Forests d. Wild life

Two Marks

1. Define conservation?
2. How do forests protect the environment?
3. What is meant by resources?
4. What are the main sources of energy in the world today?

Five Marks

1. What steps would you suggest for the conservation of forests?
2. What is the economic importance of forest?
3. What is a natural resource? Give an account of different types of natural resources?
4. What are the objectives of conservation of natural resources?
5. Give an account of non-conventional energy sources.
6. Explain seepage pit construction method.

Ten Marks

1. Describe the methods of harvesting rain water.

4. Ecosystem

a. Structure and function

Organisms interact with each other and also with the physical conditions that are present in their habitats. “The organisms and the physical features of the habitat form an ecosystem” **- Clarke** (1954). The concept of ecosystem was first put forth by **A.G.Tansley** (1935). Ecosystem is the major ecological unit. It has both structure and function. The structure is related to species diversity.

According to **E.P.Odum**, the ecosystem is the basic functional unit of organism and their environment interacting with each other. The function of ecosystem is related to the energy flow, decomposition, nutrient cycling and major biomes.

Structure

Generally ecosystems consist of two basic components.

1. Abiotic component.
2. Biotic component.

1. Abiotic components

It includes basic in-organic (soil, water, oxygen, calcium carbonates, phosphates etc.) and organic compounds. It also includes physical factors such as moisture, wind currents and solar radiation. Radiant energy of sun is the only significant energy source for any ecosystem.

2. Biotic components

Include producers, consumers and decomposers.

Producer : These are the autotrophic, chlorophyll-bearing organisms, which produce their own food.

Consumers : A consumer which gets nutrition by eating plants is called **Primary consumers** (herbivore) (eg) Rabbit, deer and cow.

The Secondary Consumer: (carnivores) is an animal that eats the flesh of herbivores (eg) cats and dogs.

Tertiary Consumers: are the type of carnivores, which prey upon other carnivores. (eg) Lion, tiger and vulture.

Decomposers

Decomposers attack the dead remains of producers and consumers and degrade the complex organic substances into simpler compounds to derive their nutrients. The decomposers play very important role in maintaining the dynamic nature of ecosystem.

Functions of Ecosystem

An ecosystem is a functional and life sustaining environmental system. The environmental system consists of biotic and abiotic components. Biotic components include living organisms and abiotic components includes in organic matter and energy.

In an ecosystem there are three functional components.

1. Inorganic constituents
2. Organism
3. Energy input

These three components interact with each other to form an environmental system. The primary producers convert inorganic constituents into organic components by photosynthesis using the energy from the solar radiations. The herbivores make use of the energy from the producers and they themselves serve as a food for the carnivores. Animals of different types accumulate organic matter in their body which is taken as food. They are known as secondary producers. The dead organic matters of plants and animals are decomposed by bacteria and fungi which break the complex molecules and liberate inorganic components. These are known as decomposers. During this process some amount of energy is released in the form of heat. The ecosystem of different habitats are interrelated with one another.

Productivity in an Ecosystem

Productivity refers to the amount of organic matter accumulated in any unit time. It is of following types.

1. Primary productivity

Green plants absorb solar energy and store it in organic form as chemical energy. This forms the first and basic form of energy storage and is known as primary productivity. It is the rate at which the organic material is formed by photosynthesis per unit area of surface per unit time.

2. Secondary productivity

It refers to consumers or heterotrophs. The consumers utilize the food materials during the process of respiration. The rate at which the food energy is assimilated is called secondary productivity.

3. Net productivity

This refers to the rate of storage of organic matter which is not used by heterotrophs. These may be equivalent to the net primary production minus consumption by the heterotrophs.

b. Energy flow

Energy

Energy is defined as the capacity to do work. There are two types of energy 1.Potential and 2. Kinetic. Potential energy is the energy at rest and kinetic energy is the energy of motion. The source of energy required by all living organisms is obtained by the chemical energy of food. The chemical energy is obtained from the radiant energy of sun. In any ecosystem, there should be unidirectional flow of energy. The flow of energy is based on law of thermodynamics.

First Law of Thermodynamics

According to this law, the amount of energy in the universe is constant. The energy can neither be created nor be destroyed but may change from one form to another.

Second Law of thermodynamics

According to this law no energy transformation takes place spontaneously unless energy is degraded. The change of energy from one form to another takes place in such a way that a part of energy is dissipated in the form of heat. Energy flows from higher to lower level.

Energy Flow

When light energy falls on green plants, it is transformed into chemical energy and stored as organic products in plants. When the herbivores consume these plants, the chemical energy is transformed into kinetic energy. During this process

degradation of energy will takes place by conversion into heat. The degradation continues when herbivores are consumed by carnivores.

Food Chain

In ecosystem, the biotic factors are linked together by food. For example, the producers form the food for the herbivores. The herbivores form the food for carnivores. "A food chain can be defined as a group of organisms in which there is a transfer of food energy, through a series of repeated eating and being eaten".

Producers $\rightarrow$ Herbivores $\rightarrow$ Carnivores.

The various steps in a food chain are called trophic levels.

Grass Land

Plants $\rightarrow$ Mouse $\rightarrow$ Snake $\rightarrow$ Hawk.

Forest

Plants $\rightarrow$ Goat $\rightarrow$ Lion.

Energy flows through food chain. The transfer of energy from one trophic level to another is called energy flow.

Types of Food Chains

The food chains are of two types, namely

1. Grazing food chain.
2. Detritus food chain.

Grazing Food Chain

The grazing food chain starts from green plants and ends in carnivores. This type of food chain depends on the autotrophs, which capture the energy from solar radiation.

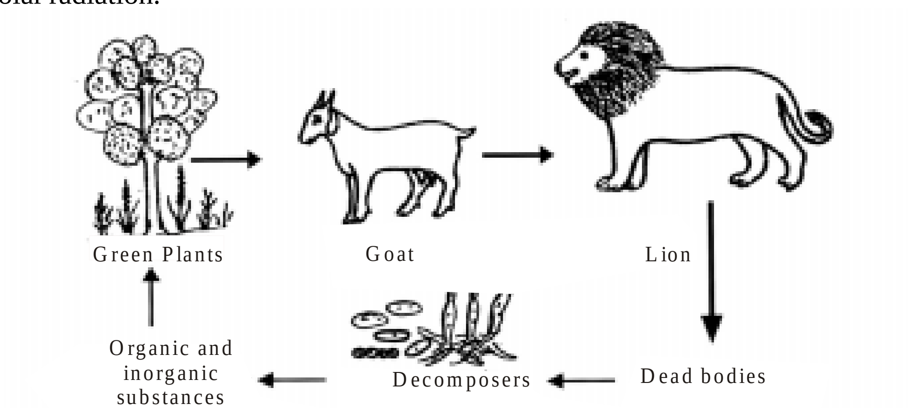


Fig.7.10 Food chain in a forest

Food Chain in Terrestrial Ecosystem

The sequence of food chains in the terrestrial ecosystem may be represented as follows.

Grassland → (Crop plants)	Rodents →	Snakes →	Hawks.
Producer	Primary consumer	Secondary consumer	Tertiary consumer

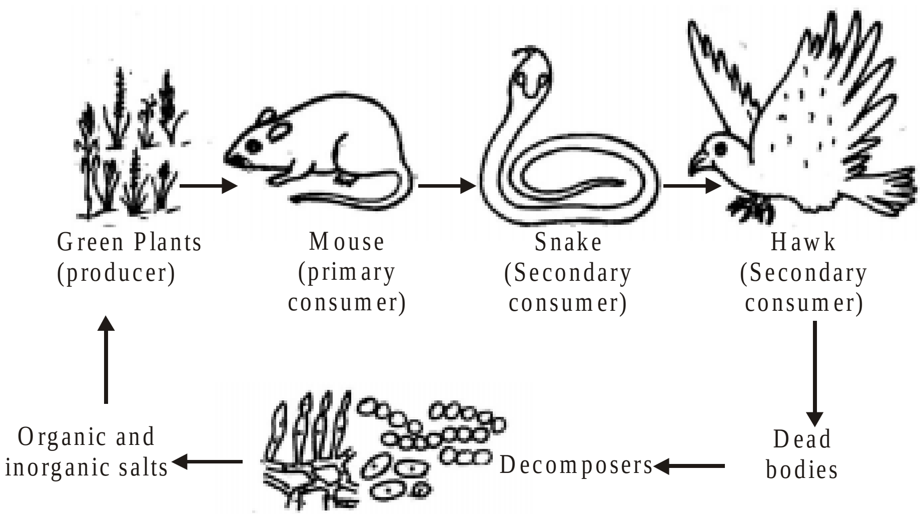


Fig.7.11 Food chain in a grassland

Detritus Food Chain

The organisms which feed exclusively on the dead bodies of animals and plants are called **Detrivores.** It includes bacteria, fungi, protozoan etc. These organisms ingest and digest the dead organic materials and convert it into CO_2 and water.

Food Web

In an ecosystem, the various food chains are inter-connected with each other to form a net work called Food Web. Simple food chain is very rare. So, each organism may obtain food from more than one trophic level.

1. Grass → Grasshopper → Garden Lizard → Hawk
2. Grass → Grasshopper → Hawk
3. Grass → Rabbit → Hawk
4. Grass → Mouse → Hawk
5. Grass → Mouse → Snake → Hawk

In grassland ecosystem, grasses eaten by grasshopper, rabbit and mouse. Grasshopper is eaten by garden lizard which is eaten by hawk. In addition hawk also directly eats grasshopper and mouse. Thus five lines are interconnected to form a food web. Food webs are very important in maintaining the stability of an ecosystem.

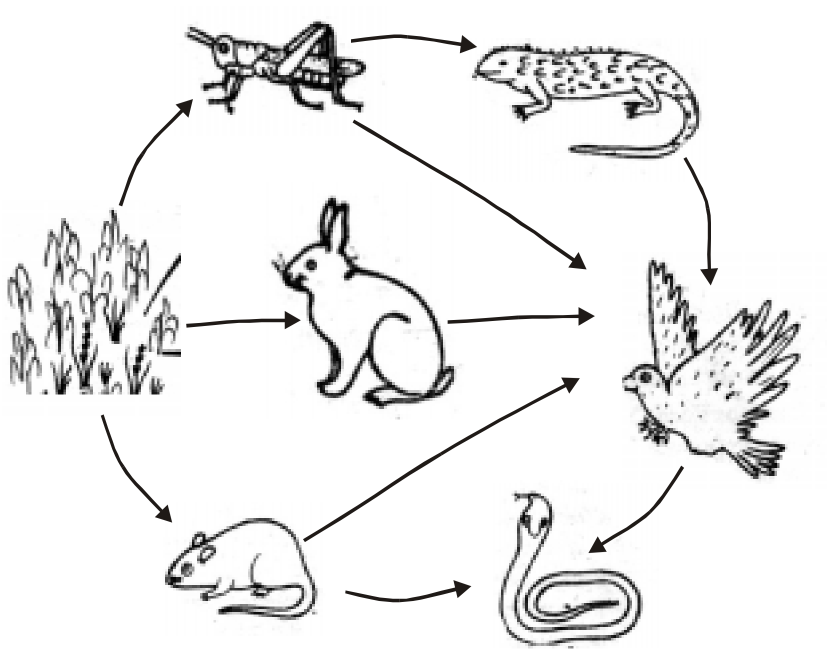


Fig.7.12 Food web in a grassland

Ecological Pyramids

The number, biomass and energy of organisms gradually decrease from the producer to the consumer level. This can be represented by a pyramid called ecological pyramid. It is the graphic representation of the number, biomass and energy of the successive trophic level of an ecosystem. The use of ecological pyramid was first described by **Charles Elton** in 1927. There are three types of ecological pyramids namely,

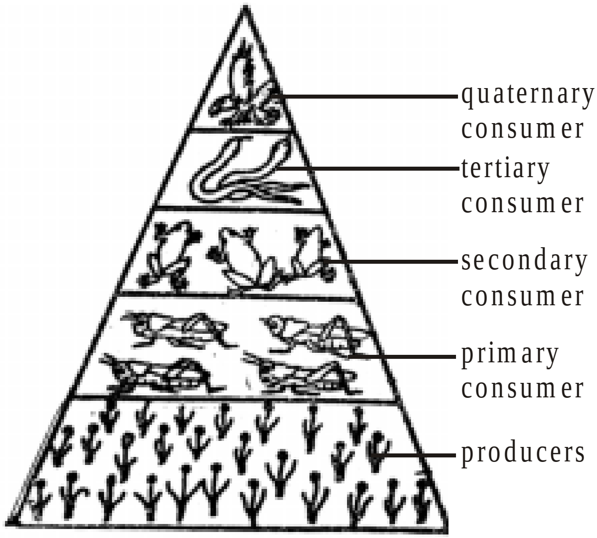


Fig.7.13 Pyramid of numbers in a grassland

1. The pyramid of numbers,
2. The pyramid of biomass,
3. The pyramid of energy.

1. The Pyramid of Number

The number of individuals at the trophic level decrease from the producer to the consumer level. In croplands the crops are more in numbers. The grasshoppers feeding on crop plants are lesser in number, The frogs feeding on grasshopper are still lesser in number. The snakes feeding on frogs are fewer in number.

In a grassland the grasses are large in numbers. The consumers decrease in the following order.

Crops $\rightarrow$ Grasshopper $\rightarrow$ Frogs $\rightarrow$ Snakes $\rightarrow$ Hawks.

2. The pyramid of biomass

Biomass refers to the total weight of living matter per unit area. In an ecosystem the biomass decreases from the producer level to the consumer level.

In a grassland the biomass of grasses is the maximum and it gradually decreases towards the consumer level.

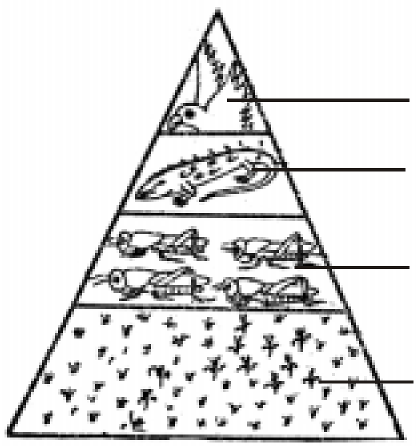


Fig.7.14 Pyramid of biomass in a grassland

Grass → Grasshopper → Garden Lizard → Hawk.

Grass → Mouse → Snake → Hawk.

In a forest, the biomass of trees is the maximum and the top consumer is the minimum. The decrease in weight occurs in the following order.

Plants → Deer → Fox → Tiger.

Plants → Rabbit → Fox → Lion.

3. Pyramid of energy

In an ecosystem, the energy flow from the producer to the consumer level will be decreasing. In a grassland, grass plants trap the maximum sun light energy. The energy gradually decreases towards the top consumer level. The chemical energy is transformed into kinetic energy.

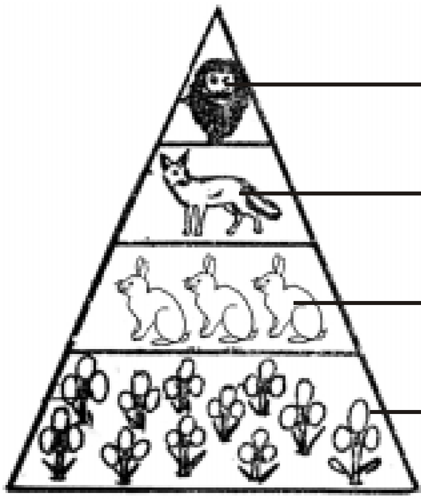


Fig.7.15 Pyramid of energy in a forest

Grass	→ Rabbit	→ Fox	→ Lion.
Grass	→ Grasshopper	→ Garden Lizard	→ Hawk.
Grass	→ Mouse	→ Snake	→ Hawk.

c. Decomposition

Decomposition refers to the break down of complex organic matter by bacteria and fungi into inorganic substances like CO_2, water and nutrients. Decomposition takes place mostly in the upper layer of the soil. The dead plants and animal parts are formed as detritus. The process of decomposition involves 3 major steps. They are 1. Fragmentation of detritus. 2. Leaching. 3. Catabolism.

1. Fragmentation of Detritus

The invertebrates feeding on detritus breaks it into small pieces and as a result the number of particles increases.

2. Leaching

A leaching action is done mainly by water, which percolates the soil and remove the soluble substances.

3. Catabolism

Various enzymes secreted by microbes convert the complex substances into simpler inorganic ones. As a result of above three processes, a dark coloured amorphous substance, called humus is formed.

Various climatic factors affect the process of decomposition. Soil moisture and temperature, latitude and altitude also influence the rate of decomposition.

d. Nutrient cycling

In an ecosystem, minerals and energy move through biotic and abiotic components. The cyclic movements of chemical elements of biosphere between the organism and their environment are referred to as **bio-geo chemical cycles**. There are two types of bio-geo chemical cycles. i.e. the gaseous and the sedimentary.

In gaseous cycles, the reservoir of nutrients is the atmosphere and the ocean. In the sedimentary cycle the reservoir is earth's crust.

Hydrological cycle

The circulation of water and moisture between atmosphere and living organisms is known as water cycle or hydrological cycle.

Water forms a significant factor of environment and without water bio-geo chemical cycle could not exist. Water from the atmosphere reaches the earth through precipitation and then it reaches the atmosphere through evaporation and transpiration.

Carbon cycle

Carbon is a basic constituent of all organic compounds. The source of carbon found in living organisms is carbon-dioxide of atmosphere. The green plants use

CO_2 through photosynthesis in the presence of sunlight to form carbohydrates. Carnivores feed on herbivores and the carbon compounds are converted into other forms. Carbon is released directly into the atmosphere by the process of respiration of plants and animals.

The decomposition of complex organic compounds by bacteria and fungi release carbon in the form of carbon-dioxide.

e. Major Biomes

Ecologically, the terrestrial habitat is sub-divided into a number of sub-units called biomes. A biome is defined as a major terrestrial community characterised by distinctive plants and animals. Example I. Forest Biome, II. Grassland Biome, III. Desert Biome.

Characteristics of Biomes

1. A biome is a major terrestrial community.
2. It is formed of distinctive animals and plants.
3. Each biome has a climax community which is dominant. The climax community forms the matrix of the biome. The biome is named after the climax community. For example, in a grassland biome, grasses form the climax community. In a forest biome, trees form the climax community. There is no clear-cut demarcation between adjacent communities. A biome is different from an ecosystem, in that the ecosystem consists of both biotic and abiotic factors. But a biome includes only plants and animals.

I. Forest Biome

A forest biome is a land of thick growth of trees. The development of forests is conditioned by a number of climatic factors, such as temperature, rainfall, availability of space and humidity.

Based on the types of plants and geographical location, forest biomes are classified into three types, namely

1. Coniferous forest

2. Tropical rain forest
3. Deciduous forest

1. Coniferous forest

This biome is thickly populated with pine trees characterised by needle-like leaves belonging to the class of Gymnosperms. The leaves of the trees are evergreen. They are restricted to northern hemisphere. Heavy rainfall and humidity are the climatic features of this forest. It is also called "Taiga" because it gives thick shade and prevents the growth of herbs and shrubs. The seeds of pine trees form the major source of food for certain animals.

Flora: *Pinus, Cedrus* and ***Cupressus***

2. Tropical Rain Forest

These forests are found in the tropical zone of the world where very high temperature and abundant rainfall is seen. Trees are very high with woody stems. The leaves are broad and evergreen. In this forest the productivity is very high. It is formed of three layers namely an upper layer of leaves and branches, a middle layer of shrubs and small trees and a lower layer of forest floor.

Flora : *Bauhinia, Bambusa* and ***Sterculia***

3. Deciduous Forest

These forests are found in India, Australia, Europe and U.S.A. This forests have tall trees with broad and thin leaves which fall during winter. During summer the days are long and the climate is warm. During winter the days are short and climate is cold. During autumn the trees shed their leaves and remain in dormant condition.

Flora : Teak, *Shorea* and ***Terminalia***

II. Grassland Biome

This type of habitat is seen in major part of the world (North America, Asia, Siberia, Russia and Africa). The plain lands are occupied by grasses. Grasses form the climax community in this biome. Grassland biome is also called Prairies,

Steppes, Pampas etc. Rainfall is irregular with strong winds which help to increase dryness and avoid the growth of trees.

Flora : ***Andropogon***, ***Saccharum*** and ***Cenchrus***

III. Desert Biome

A desert is a waterless, treeless, large waste land and often covered with sand. Scarcity of water, extreme temperature and dust storms are the characteristic features of this biome. Deserts are classified into two groups, namely hot-deserts and cold deserts. In hot deserts the temperature is very high. (eg.) Sahara, Kalahari (Africa), Rajasthan (India) and Gobi (China). In cold deserts, the temperature is very low. They are situated at high altitudes. (eg.) Tibet, Alps, Scandinavian mountains etc.

Flora : ***Opuntia*** (Cacti), ***Zizyphus*** and ***Calotropis***

Self Evaluation

Two Marks

1. What is a food chain?
2. What is a food web?
3. Give an account of decomposition.
4. What is meant by nutrient cycle?

Five Marks

1. Give an account of productivity in ecosystem.
2. Explain the different types of food chains with example.
3. What is a biome? Explain with an example.

Ten Marks

1. Write an essay on structure of ecosystem.
2. Give an account of energy flow in an ecosystem.
3. Write an essay on ecological pyramids.

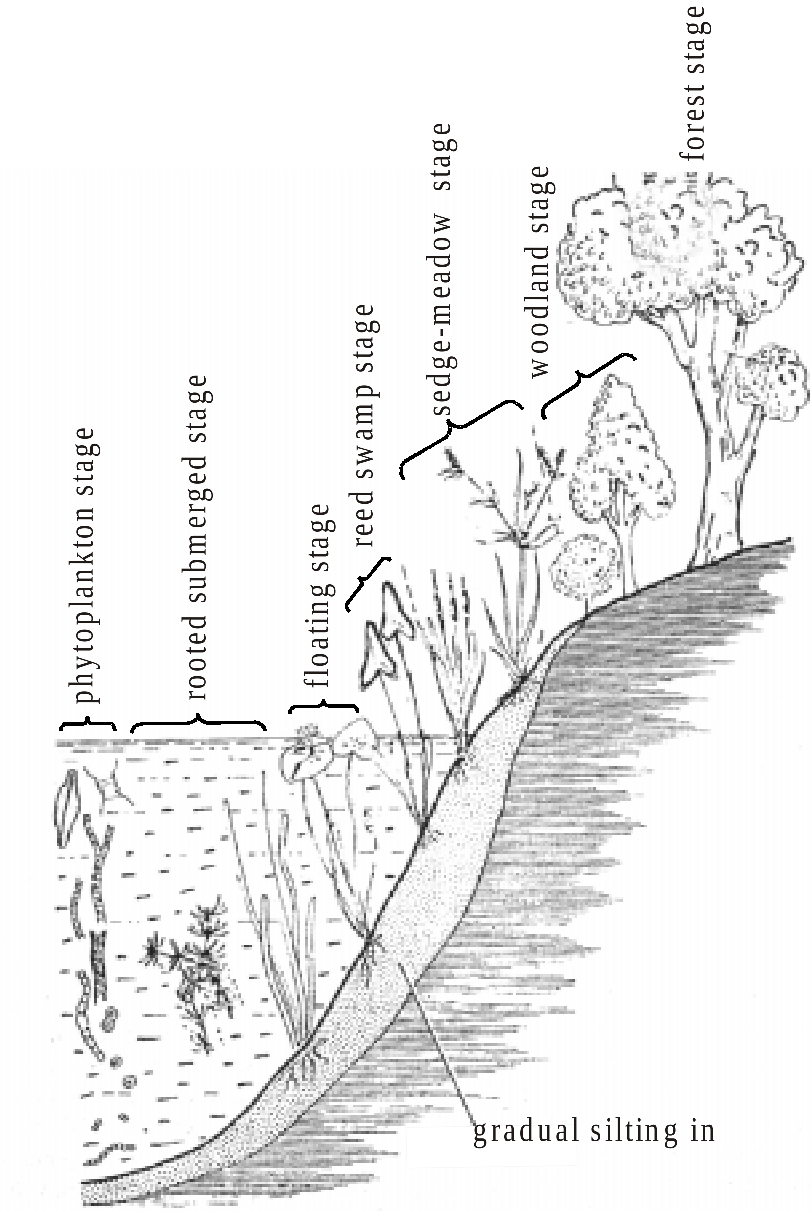


Fig.7.16 Hydrosere succession

5. Ecological Succession (Mechanism and types)

Hydrosere and Xerosere

The vegetation occupying a given habitat is called plant community. The community passes through several developmental stages in a definite sequence from simple to complex. The gradual replacement of one type of plant community by another is known as plant succession. **E.P. Odum** defines plant succession as an orderly process of community change in an unit area.

According to Clements succession is a natural process by which the same locality becomes successfully colonized by different groups of communities. Such an orderly and progressive replacement of one community by another until a stable community called climax community occupies their area is called **ecological succession.**

The different stages of plant succession taking place at a particular habitat is known as **sere.** The first plants which appear on the bare habitat are called pioneer plants. After several changes, a habitat becomes occupied by most tolerant species which forms a climax community.

Hydrosere

It is a type of succession taking place in an aquatic environment. In a virgin pond, hydrosere starts with a colonization of phytoplanktons and finally reaches a climax forest stage. The different stages of succession are given below.

1. Phytoplankton Stage

This is the initial stage of succession. Phytoplanktons, and zooplanktons are the pioneer colonizers. These organisms add large amount of organic matter and nutrients, which settle at the bottom of pond.

2. Rooted submerged stage

As a result of death and decomposition of phytoplanktons a soft mud develops at the bottom of pond. This new habitat now becomes suitable for the growth of rooted hydrophytes like ***Myriophyllum, Elodea, Hydrilla, Potomogetan, Vallisneria, Utricularia*** etc. These plants further build up the substratum. This

new habitat now replaces these plants giving way to another type of plants of floating types.

3. Floating stage

In the beginning the submerged and floating plants grow intermingled but very soon the submerged plants are replaced completely. The habitat becomes changed chemically as well as physically. The dead remains of plants are deposited at the bottom. The substratum rises up in vertical direction. The important plants of this stage are ***Nelumbium, Trapa, Pistia, Nymphaea*** and ***Limnanthemum.***

4. Reed-swamp stage

This stage is also known as 'amphibious' stage as the plants of this community are rooted but most parts of their shoots remain exposed to air, species of ***Scirpus, Typha, Sagittaria*** and ***Phragmites*** etc. are chief plants of this stage. Their rhizomes form a dense vegetation. The water level is very much reduced and becomes unsuitable for growth of these amphibious species.

5. Sedge meadow stage

Further decrease in water level changes the nature of substratum. Species of some Cyperaceae and *Gramineae* such as ***Carex, Juncus, Cyperus*** and ***Eleocharis*** colonise the area to form marsh or swamp. Thus mesic conditions approach the area and marshy vegetation disappear gradually.

6. Woodland stage

In the beginning some shrubs and later medium sized trees form open vegetation or ***woodland.*** These plants produce more shade. They render the habitat more dry. The prominent plants of woodland community are species of ***Butea, Acacia, Cassia, Terminalia, Salix, Cephalanthus*** etc.

7. Forest stage

This is the climax community invaded by several trees. In tropical climate with heavy rainfall there develop tropical rain forests. In temperate regions, mixed forest of ***Almus, Acer*** and ***Quercus*** are formed.

Xerosere

The Xerosere originates on rock surfaces which is in an unweathered state. The pioneers to colonize these primitive type of substratum are lichens. In a Xerosere successive changes take place in both plants and also in animals. The various stages are described below.

1. Crustose - lichen stage

The soil is absent for the complete penetration of roots. Blue-green algae and lichens are the pioneer species. In cooler climates, crustose lichens like ***Rhizocarpon, Rinodina*** and ***Lecanora*** are the common pioneers. They produce acids which bring about weathering of rocks. The dead organic matter of algae and lichens become mixed with the small particles of rocks to form a thin layer of moist soil on the rocks.

2. Foliose - lichen stage

They appear on the substratum partially built up by the crustose lichens. It includes species of ***Parmelia, Dermatocarpon*** which have large leaf-like thalli. The weathering of rocks mixed with humus results in the development of a fine thin soil layer on rock surface and thus there is a change in the habitat.

3. Moss-stage

The development of thin humus-rich soil layer on rock surface favours the growth of certain xerophytic mosses such as ***Grimmia, Tortula, Polytrichum, Bryum, Barbula*** and ***Funaria.***

4. Herb-stage

Due to the extensive growth of mosses, more soil accumulates. Minerals are added to it due to leaching. This favours the growth of some herbaceous plants like ***Aristida, Festuca, Justicia, Tridax*** etc.

5. Shrub-stage

Due to much accumulation of soil, the habitat becomes suitable for shrubs. Species of ***Rhus, Phytocarpus, Zizyphus*** and ***Capparis*** dominate this stage. The shrubs overshadow the herbaceous vegetation and produce more organic matter.

6. Forest - stage

It represents the climax community. Due to the weathering of rocks, thin layer of soil is formed, which supports small trees like ***Acacia, Prosopis, Boswellia*** etc. Plants require high rainfall to reach climax stage. In moist and wet climates and also in temperate climates dense climax forest is developed.

SELF EVALUATION

One mark

Fill in the blanks

1. Different stages of plant succession taking place at a particular habitat is known as__________________
2. The pioneer colonizers are____________________ and ___________.
3. _________________ community invaded by several trees.
4. In a xerosere the pioneering community to colonize is__________________.
5. ___________________ is a great Ecologists

Five marks

1. Define phytoplankton
2. Define Reed-Swamp stage

Ten Marks

1. Explain the various stages of hydrosere.
2. Explain the various stages of xerosere.
3. What is Ecological succession? Explain.